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ABSTRACT

This module is the ninth in a series of eleven modules in an energy conservation curriculum for secondary and postsecondary vocational students. It is designed for use by itself or as part of a sequence of four modules on energy conservation in building construction and operation (see also modules 8, 10, and 11). The objective of this module is to train students in the recognition, implementation, and utilization of energy conservation for creature comfort and thermal control. First, an introduction to the module and definitions of key terms are provided. Next, the text is presented in the following three units: (1) the nature of thermal comfort in humans; (2) how natural climates and artificial environments are defined; and (3) controlling buildings for thermal comfort. The information in each unit is presented in lecture format accompanied by laboratory exercises and questions/examples for class discussion. A bibliography and several charts illustrating the text material are found at the end of the module. (BM)

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Energy Conservation Curriculum for Secondary and Post-Secondary Vocational Students. Module 9.

HUMAN COMFORT AND ENERGY CONSERVATION

BEST COPY AVAILABLE

NAVARRO COLLEGE
CORSICANA, TEXAS

April, 1979

U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
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MODULE #9

HUMAN COMFORT AND ENERGY CONSERVATION

This module is one of a group of 11 modules in an energy conservation curriculum for secondary and post-secondary vocational students. Human Comfort and Energy Conservation may be offered by itself or as part of a sequence of 3 modules in the following order:

Order	Module	Title of Module
1	9	Human Comfort and Energy Conservation
2	8	Building Construction vs Energy Consumption
3	10	Heating, Ventilating, and Air Conditioning Conservation Opportunities

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MODULE #9

HUMAN COMFORT AND ENERGY CONSERVATION

INTRODUCTION:

This block of instruction is an introductory study of the integration of human comfort variables. These variables include physical, demographic, and personal differences which affect the relationship between human comofrt and energy use. Some of the variables examined include air temperature, humidity, air movement, geographical location, age differences, type of activity engaged in, and kinds of clothing worn.

COURSE DESCRIPTION:

The student will be given an overview of the ways energy is used to maintain human comfort and some approaches to reducing energy use through conservation. The central ideas of this module revolve around the nature of creative comfort and the principles of temperature control.

OBJECTIVE:

The objective of this module is to train secondary and post-secondary individuals in the recognition, implementation, and utilization of energy conservation for creature comfort and thermal control.

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GOAL STATEMENT

Upon completion of this module, the student will be able to readily relate thermal comfort in humans to:

a. Temperature measurements,

b. Person-to-person differences,

c. Seasonal and geographic differences, and

d. The human comfort zone.

UNITS:

1. The Nature of Thermal Comfort in Humans
2. How Natural Climates and Artificial Environments are Defined
3. Controlling Buildings for Thermal Comfort

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MODULE #9
HUMAN COMFORT AND ENERGY CONSERVATION

TERMINOLOGY

acclimation - the process of result of adapting to a new temperature, altitude, climate, environment, or situation.

air velocity - speed at which air moves with respect to a designated reference point (it has both on speed and a direction.)

anemometer - an instrument for measuring and indicating the force or speed of the wind.

black-bulb (globe) thermometer - a thermometer whose sensitive element has been made to approximate a blackbody by covering it with lampblack used for globular measurements.

British Thermal Unit - the quantity of heat required to raise the temperature of one pound of water one degree Fahrenheit.

calorie - the amount of heat required at a pressure of one atmosphere to raise the temperature of one gram of water one degree centigrade.

carbohydrate - any of various neutral compounds of carbon, hydrogen, and oxygen (as sugars, starches, and celluloses) most of which are formed by green plants and which constitute a major class of animal foods.

climatology - the science that deals with the course or condition of the weather at a place over a period of years as exhibited by temperature, wind velocity, and precipitation.

"clo" - the unit of measurement for thermal insulation values of clothing.

cold-blooded - having a body temperature not internally regulated but approximately that of the environment, dependent on external climatic factors.

comfort zone - the ranges of indoor temperature, humidity and air movement under which most persons enjoy mental and physical well-being.

conduction - the transfer of heat through direct contact between two or more conductors of heat which are at different temperatures.

convection - the transfer of heat by the automatic circulation of a fluid due to a temperature gradient.

dry bulb temperature - the actual air temperature or that of dry air as measured by an ordinary thermometer not dependent upon atmosphere humidity.

humidity - a measure of the amount of water vapor in the atsmophere or air. (Usually given as "relative humidity", % of maximum moisture capacity from the dry bulb temperature.

insulation - material used to separate conducting bodies by means of a method that is less conductive in order to reduce the transfer of electricity, heat, or sound energy.

isotherm - a line on a map or chart of the earth's surface connecting points having the same temperature at a given time or the same mean temperature for a given period.

kilocalorie - the amount of heat required to raise the temperature of one kilogram of water one degree centigrade: 1000 gram calories or 3.968 BTU.

kilogram - the basis metric unit of mass and weight equal to the mass of a platinum-iridium cylinder kept at the International Bureau of Weights and Measures near Paris and nearly equal to 1000 cubic centimeters of water at the temperature of its maximum density.

non-acclimatized - opposite of acclimatized. (See acclimatization.)

protein - any of numerous naturally occurring extremely complex combinations of amino acids that contain the elements carbon, hydrogen, nitrogen, oxygen, usually sulfur, and occasionally other elements (as phosphorus or iron), are essential constituents of all living cells, and are synthesized from raw materials by plants but assimilated as separate amino acids by animals.

psychrometer - a device comprising two thermometers, one a dry bulb for measuring a temperature, the other a wet or wick-covered bulb for determining the moisture content or relative humidity of air or other gases.

radiant heat - energy transmitted by radiation. The amount of energy radiated bu anybody is proportional to the fourth power of the absolute temperature.

relative humidity - the ratio of the amount of water vapor actually present in the air to the greatest amount possible at the same temperature.

solar radiation - the complete spectrum of electromagnetic radiation and particles emitted by the sun.

sub-tropical zone - of, relating to, or being the regions bordening on the tropical zone. This corresponds to the general region which is located on latitudes of 20° to 30° N and S of the equator.

temperature zone - the area or region between the tropic of Cancer and the arctic circle or between the tropic of Capricorn and the antarctic circle. Dependent also on altitude near the tropics located next in increasing latitude to the sub-tropical zones.

thermal energy - the mean energy a particle of air has as a function of ambient temperature based on the ideal gas law.

thermograph - an instrument that senses, measures, and records the temperature of the atmosphere.

tropic zone - the region located on both sides of the equator below the two tropics in latitude or roughly the belt from 20° N to 20° S latitude.

warm-blooded - having a constant body temperature dependent upon internal control and relatively independent of the surroundings.

wet-bulb temperature - the air temperature as measured by a thermometer having the bulb covered with a cloth, usually muslin or cambric, saturated with water. Determines the relative humidity of the air.

OUTLINE

LECTURE

MODULE 9: Human Comfort and Energy Conservation

Performance Objectives for Module 9.

Upon completing this module, the student will readily relate thermal comfort in humans to:

(a) Temperature measurements

(b) Person-to-person differences

(c) Seasonal and geographic differences

(d) The human comfort zone

LABORATORY

MODULE 9: Human Comfort and Energy Conservation

Laboratory Objectives for Module 9

Upon completing this module, the student will have been exposed to equipment and methods for making observations relative to human comfort and energy use, and will have accomplished useful data measurements. Discussion and hands on experience will have illustrated many of the principles described in the lectures.

UNIT 1: The Nature of Thermal Comfort in Humans

a. Thermal energy in humans and other animals.

b. Effects of heat and cold.

c. Survival and comfort.

d. Clothing, food, water, and health.

Materials and Equipments:

a. Sling psychrometer

b. Blackglobe thermometer

c. Vane gauge anemometer and fan

d. Thermographs

e. Clinical thermometers

OUTLINE

LECTURE	LABORATORY
UNIT 2: How Natural Climates and Artificial Environments are Defined	Materials and equipment:
a. Characteristics of hot and cold.	a. Maximum-minimum recording thermometer
b. Air movement and humidity.	b. Pad of psychometric charts
c. Natural outdoor conditions vs season and geography.	c. Monthly summary of weather observations for nearest NOAA Station, plus the materials and equipment listed in Unit 1.
d. How human comfort zones are measured.	
UNIT 3: Controlling Buildings for Thermal Comfort	Materials and equipment:
a. Occupancy and duration	a. Circular-chart temperature recorder.
b. Activity and clothing	b. Wall-type thermostats
d. Energy-saving options	c. Access to hot and cold work places, i.e., nearest factory, garage, workshop, refrigerator or cold storage area, plus the materials listed in Lessons 1 and 2.

UNIT 1: The Nature of Thermal Comfort in Humans

Goal Statement:

Lesson 1 is one of three lessons within the module Human Comfort and Energy Conservation. This lesson addresses the basic facts of thermal energy generation from food, and the conservation of thermal energy by the human body. Heat losses and heat gains are described as they are related to survival, comfort, clothing, food/water intake, and health.

LECTURE	LABORATORY ACTIVITIES

UNIT 1:

a. Thermal Energy in Humans and Other Animals

Humans are warm-blooded animals, and therefore possess thermal energy. this means they maintain a relatively constant and warm body temperature independent of environmental conditions. Humans, domestic animals (cats, dogs, etc.), and farm animals (horses, cattle, etc.) are warm-blooded mammals. Many wildlife species (reptiles, snakes, insects, etc.) are not warm-blooded and do not radiate thermal energy. Still other animals (bears, beavers, squirrels) hibernate in winter but are warm-blooded in summer.

All animals derive the energy for maintaining body functions, including temperature from food they consume. This energy is measured in British Thermal Units (BTUs) or Kilocalories. A British thermal unit or BTU is a unit of measurement for energy which stands for the quantity of heat required to raise the temperature of one pound of water by one degree Fahrenheit. Whatever energy is not consumed for life processes such as breathing, blood circulation, and growth, or for movement such as travel, exercise, lifting,and working is dissipated as thermal energy. Some of this is lost directly through exhaling, conduction, convection. The remainder is used to maintain body temperature.

a. Measure your body temperature with a clinical thermometer. It will be somewhere in the range of 97°- 100°F (36.1-37.8°C) unless one of the special conditions which are listed on the body temperature chat applies. (Figure 1.1) 98.6°F is a common average temperature when measured in the human mouth. Record the lowest, average, and highest mouth temperatures in your class. Take temperatures with a thermometer under the area. Is there a difference?

The supply of thermal energy depends upon body size and food supply. Active adults require more food than babies, children, sick persons, or the old and inactive. Children, however, require more food and energy per unit mass because of growth and the surface to volume ratio. Large humans and other animals generate more thermal energy than small humans and small animal species. In general, mature females are somewhat smaller and lighter than mature males, therefore, they eat and need less food and thermal energy. There are many exceptions, however, such as pregnant or lactating women, active vs sedentary persons, outdoor vs indoor workers.

The amount of energy in food and drink is well known to nutritionists, food suppliers, physicians, and weightwatchers. These are catalogued in nutrition books and diet pamphlets readily available on the market. An adult person who does not use up all of his/her food for maintaining normal metabolic body functions will gain weight. In general, smaller animals in smaller mass and larger surface to volume ratios require more food and food energy per unit mass. By contrast, one who uses up more thermal energy than food supply will lose weight.

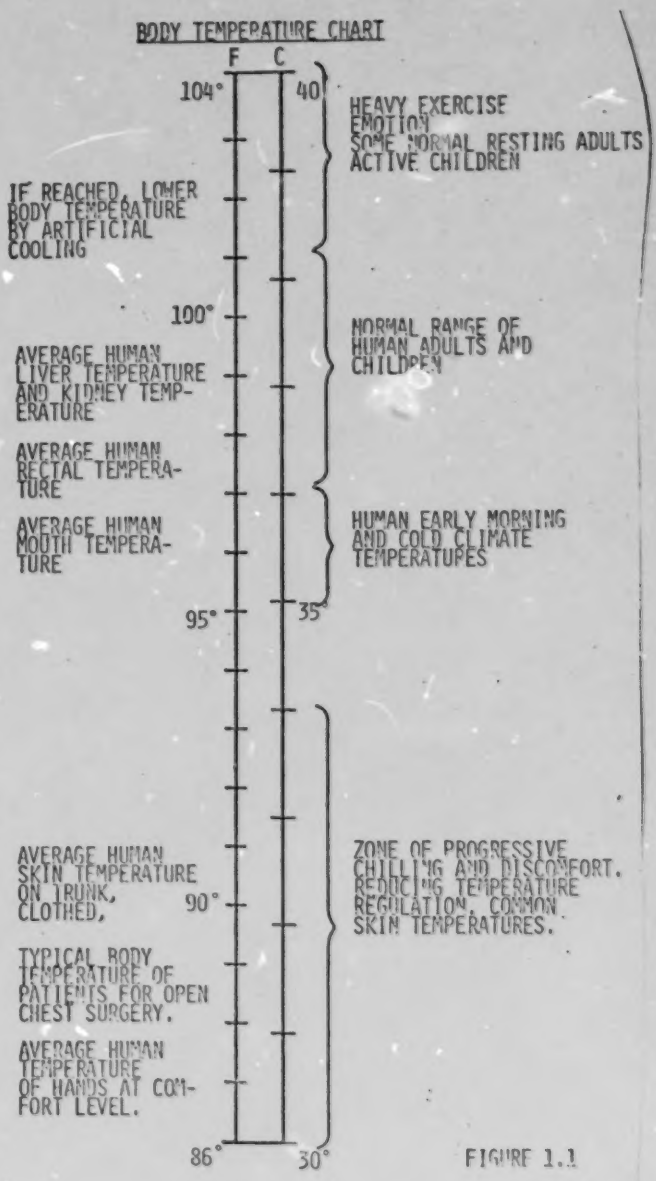

FIGURE 1.1

UNIT 1:

b. Effects of Heat and Cold

Any part of your skin not covered by clothing or hair is called "exposed skin," because it is exposed to the thermal conditions of the surrounding air. This skin is more sensitive to changes in temperature, radient energy (sunlight), and wind speed of the surroundings. If the air is hotter than the skin, thermal energy will move from air through skin to the body core. If allowed to continue, the deep body temperature, including mouth temperature, will begin to rise. If the air is colder than skin, thermal energy will move from the body core through the skin to the air. If allowed to continue, the deep body temperature, including mouth temperature, will begin to fall.

The rate of body temperature rise or fall will depend on four (4) factors:

(1) air-skin temperature difference,
(2) rate of air movement,
(3) amount of humidity in the air,
(4) surface-skin temperature difference of adjacent walls, surfaces, or panels.

In order to prevent any large rise or fall in temperature, the body will usually adapt reflexively or behaviorally to compensate or adjust for external temperature changes. Discuss the two (2) following tables. (figures 1.2 and 1.3)

COMPENSATORY RESPONSES

	THERMAL SURROUNDINGS	HEAT PRODUCTION CHANGE
1	COLD AIR WINTER SEASON COLD CLIMATES	INCREASED PHYSICAL ACTIVITY INCREASED FOOD INTAKE DECREASED FLUID INTAKE AND SWEATING
2	HOT AIR SUMMER SEASON HOT CLIMATE	DECREASED PHYSICAL ACTIVITY DECREASED FOOD INTAKE INCREASED FLUID INTAKE AND SWEATING

COMPENSATION IS OVER A PERIOD OF TIME AND IS PARTLY VOLUNTARY.

FIGURE 1.2

b. To show that skin temperature changes, select two students with characteristically different skin pinkness (flushing) at the beginning of class, and show by touch that skin flush is accompanied by warmth, and skin turning pale is indicative of a cool surface temperature. Have individual students compare forehead, nape of neck, back of hand, palm of hand, and foot temperatures. In many cases, there will be substantial differences in skin temperature and skin color.

To show the effects of air movement, have the students blow gently on the backs of their hands or pass in front of a moving fan to sense coolness. Use a vane gauge aerometer to show that the higher the air movement the cooler the sensation of exposed skin.

To show the effects of humidity in the air and on the skin, moisten skin. Now repeat. Using a sling psychrometer, show that the air is usually humid, or has a higher relative humidity early in the day and while near trees/vegetation/water, than late in the day and indoors/away from vegetation and water. Which situations feel coolest?

To show the effects of surface temperatures and radiation, use one or more black globe thermometers mounted (a) in sunshine; (b) near hot surfaces, such as hot walls, stoves, running motors; (c) near cool surfaces, such as cold windows, cool floors or walls, and outside a refrigerator door. Can the skin detect heat flow towards or away from a surface (a) by touch and

ADJUSTMENTS TO SKIN HEAT LOSS

	THERMAL SURROUNDINGS	SKIN-BLOOD FLOW CHARGE
1	COLD AIR LOW THERMOSTAT SETPOINT LOW SURFACE TEMPERATURES	BLANCHES SKIN, REDUCED BLOOD FLOW, LIMITED SWEATING, SHIVERING; INCREASED HEAT PRODUCTION
2	HOT AIR HIGH THERMOSTAT SETPOINT HIGH SURFACE TEMPERATURES	PINK SKIN, INCREASED BLOOD FLOW SWEAT RATE RAISES; INCREASED HEAT LOSS; AREA OF MOIST SKIN INCREASED

ADJUSTMENTS ARE RAPID AND CONTROLLED BY NERVOUS REFLEX.

FIGURE 1.3

(b) by holding nearby without touch? NOTE: A black globe thermometer measurers the effects of radiant heat entering or leaving a matt-black copper globe, usually 5-6 inches in diameter.

To show that skin appearance and sweat rate are different in cold surroundings vs. hot surroundings, class members might visit and observe persons in cold and hot workplaces, e.g., nearest factory, kitchen, walk in refrigerator, or cold storage area. Describe and record the observations and personal sensations of skin coolness or warmth.

UNIT 1:

c. Survival and Comfort

For short periods of time, humans can withstand extreme degrees of heat and cold. The more extreme the temperature, the shorter will be the tolerance time and the greater will be the stress and discomfort. At very high and very low temperatures, such as working near a blast furnace or in a meat locker, protective clothing is needed for life survival. Discuss th relation between tolerance time and temperature as shown on the temperature-time survival chart, Figure 1.4.

TEMPERATURE-TIME SUPVIVAL CHART

THE MAN-MADE ENVIRONMENT-TEMPERATURES FOR HUMAN SURVIVAL IN AIR

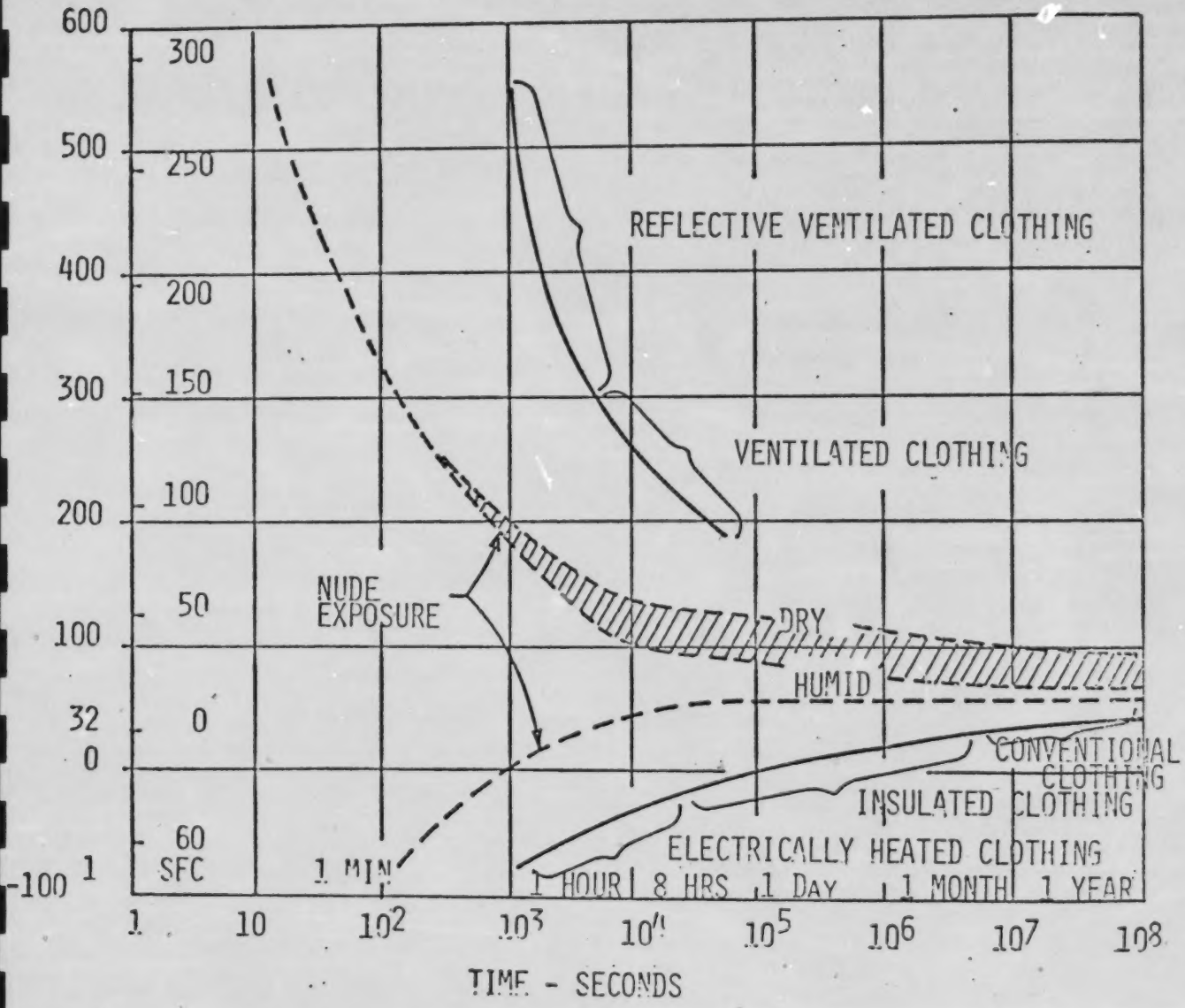

FIGURE 1.4

Note that for one hour exposure, a person wearing special protective clothing can withstand -40°F (-40°C) to +320°F (+160°C). If exposed without clothing, a person could only withstand +40°F (+5°C) to +170°F (+77°C), and +40°F (+5°C) to -130°F (-90°C) in hot, humid conditions. Frostbite, deep body chilling, heat prostration, and heat stroke are potential causes of death.

c. A working day is usually regarded as 8 hours. Using the graduated scale on the guide, request that each student note feelings at the temperature of the classroom or laboratory, remembering the duration of the class is only 1-2 hours. How would the student react if the temperature were:

(a) 60°F (16°C) for 8 hours (Note: this temperature is close to the lower limit of exposed survival).
(b) 100°F (38°C) for 8 hours (Note: this temperature is close to the upper limit of exposed survival).
(c) 60°F (16°C) for 1 hour
(d) 100°F (38°C) for 1 hour
(e) 70°F (21°C) for 1 year

(Figure 1.5 is a "Comfort Score Guide")

COMFORT SCORE GUIDE

THE DESCRIPTIONS BELOW REPRESENT THE GRADUATING SCALE FOR INDICATING DEGREES OF COMFORT.

1. COLD
2. COOL
3. SLIGHTLY COOL
4. COMFORTABLE
5. SLIGHTY WARM
6. WARM
7. HOT

FIGURE 1.5

LECTURE	LABORATORY
Note that 8 hour/shift work is usually 8 a.m. to 4 p.m., 4 p.m. to 12 midnight, 12 midnight to 8 a.m., or some similar pattern, and that temperature conditions at the workplace may be considerably cooler during the 12 midnight to 8 a.m. shift because these are hours of darkness. When was the highest daytime temperature recorded in your locality yesterday? At which shift was comfort likely to be least? (Hint: See today's newspaper report of local climatology.)	
For persons confined to the home, such as babies, sick persons, or the handicapped, there would be very narrow temperature limits for survival. This is why newborn babies are often placed in incubators, and why the very old are often very uncomfortable at certain times of the day or night cycle, even while in their own homes.	Why is this? (Hint: See the extreme right hand side of the Temperature-Time Survival Chart (Fig. 1.4) which indicates a one-year duration).
To determine the temperature at various times of day 24-hour thermographs are used. A thermograph is a recording thermometer whose temperature readings are charted on a circular paper chart or on a stripchart drum. They are used to determine when, and for how long, the air temperature has fallen outside comfort limits.	Mount a thermograph close to the largest available classroom/laboratory window, and another near a suitable secure location just outside (i.e., a fire escape or roof). Record yesterday's readings and compare them. Were there major temperature differences between day and night outside? Did the indoor temperature record show any form of cyclical change? Were the hours of high and low temperature similar inside and outside the classroom/-laboratory windows?
UNIT 1:	
d. Clothing, Food Water and Health	
Clothing covers a variable proportion of skin, provides thermal insulation, and prevents hot or cold air from moving over clothed portions. The unit of measuring thermal insulation is a "clo". If single-layer, light, woven fabrics are used, there can be heat exchange and	

moisture passed through the cloth, and the overall thermal insulation, measured in "clo" units, might be 0.15-0.40. If several layers of indoor garments are worn, heat exchanges and moisture evaporation are reduced, and the layered clothing insulation would probably be 0.40-0.80 clo units. Winter and outdoor clothing have lined or fur-insulated construction, usually of 0.8-2.0 "clos". The best quality Arctic winter protective ensembles, when measured using electrically heated copper manikins can insulate no better than 25 times lightweight clothing--i.e., 2.0-4.0 "clos".

Clothing styles have changed in recent years from an average indoor "clo" value of about 0.9 in men and women to:

CLOTHING ENSEMBLE CLO VALUES

	An average of 12 sedentary indoor clothing ensembles.	Light, summer, sub topical.	Heavy, winter, Northern USA.
MEN	0.76	0.38	1.18
WOMEN	0.74	0.27	1.20

(All values in clo units)

FIGURE 1.6

Individual garments have "clo" values in the range 0.01-0.03 (pantihose and socks) to 0.49-0.63 (light jacket and warm dress). Men and women usually adopt distinctly different cool-weather and hot-weather dress styles. By so doing, they change the thermal insulation, the proportion of skin covered, and the tolerance to heat or cold. By repeated exposure to the changing heat or cold of summer or winter, they become seasonally or residentially accustomed to climate and temperature--a process known as "acclimatization" or "adaptation", and requiring several days or weeks for full accomplishment. The heat acclimatized person feels more comfortable than the non-acclimatized person in warm surroundings, and the cold acclimatized person feels more comfortable than the non-acclimatized person in cold surroundings. Thus, two people with different clothing ensembles or different acclimatization backgrounds may note different degrees of comfort, even if they work at adjacent desks.

Clothing materials possess other qualities whihc are important in comfort and care. Wool, for instance, is a material which maintains its insulation or "clo" value even when wet. That is one reason it is a material used in cold climates. It is also very good in absorptivity which is important when persperation occurs in an activity. It is not good, however, in shedding water amd rain.

Food is digested and is generated into body heat in from 4-6 hours after eating, depending on type and quantity. Carbohydrates (pastries, bread, sugar, candies) succeed quickly in producing heat and in raising stored body energy. Fatty foods (dressings, spreads, fried dishes, fatty meats) require longer than any other food for full digestion and release of heat. Proteins (meat, fish, eggs) stimulate the conversion of stored body fat into energy releasing carbohydrates. Discuss Figure 1.9.

To show that considerable variation exists in clothing worn, have class members inventory the garments they are presently wearing in the classroom. What changes in the inventory would they expect on a) very hot days, or b) very cold days? Using the Table on Individual Garments in Figure 1.7, assign "clo" values to each garment worn. Add up and compare total "clo" units per person. How do they compare? Discuss the reasons for differences between "clo" units of various class members. (i.e. a person with a slight cold or fever will have a clothing "clo" value total higher that a person who has just come from gym class after running and playing). Discuss seasonal change of "clo" values.

Discuss the various qualities of different materials listed in Figure 1.8. What types of material would one consider for various activities, such as:

a. tennis outdiirs in winter?
b. tennis outdoors in winter?
c. watching a parade in a sunny but cold day in January?
d. watching a parade on a hot July 4th?
e. hiking in May?
f. hiking in December?

Under what conditions would each of the material qualities be considerations before purchasing?

Review your school menu or food vending machines. What items are sold? Which classes of food (e.g., snacks) would persons who felt uncomfortably cool consume. Uncomfortably warm? On starting a mid-shift lunch break after doing four hours of hard work? Is it important to expend energy to change the temperatute of a snack? Does a hot beverage produce sweating which in turn lowers or cools body temperature?

FIGURE 1.7

INDIVIDUAL GARMENTS: INSULATION IN CLO UNITS

INSULATION VALUE *	MEN	WOMEN
0.01	-	PANTIHOSE
0.02	SANDALS	SANDALS
0.03	COOL SOCKS	COOL SOCKS
0.04	SHOES	GIRDLE
0.05	BRIEFS	BRAS & PANTIES
0.06	UNDERSHIRT	MINI SKIRT
0.09	T-SHIRT	SUMMER SHIRT
0.14	COOL L.S. KNIT SHIRT	HALF SLIP
0.19	WOVEN S.S. SHIRT	SUMMER BLOUSE
0.26	SUMMER TROUSERS	SUMMER PANTS
0.29	WOVEN L.S. SHIRT	P.S. BLOUSE
0.32	WARM TROUSERS	-
0.37	L.S. WINTER SWEATER	L.S. WINTER SWEATER
0.49	WARM JACKET	WARM DRESS
0.63	-	

* CLO VALUES ARE ADDED FOR EACH GARMENT WORN IN AN ENSEMBLE TO OBTAIN OVERALL CLOTHING INSULATION.

CLOTHING MATERIAL CHARACTERISTICS

	Cotton	Linen	Wool	Silk	Acetate	Triacetate	Acrylic Modacrylic	Nylon	Olefin	Polyester	Rayon
Absorbency	+	+	+	+	-	-		-		-	+
Appearance & Hand				+	+	+	+				+
Colorfastness	+	+	+	+	-		+	+		+	+
Dimensional stability		+		+	+	+	+/-	+		+	-
Drapability				+	+	+					+
Durability		+									
Dyeability	+		+	+					-		+
Elasticity								+			
Laundrability	+										
Pressed-in crease retention	-	-	+	-	-		+			+	
Resiliency			+				+	+		+	-

FIGURE 1.8

	MODACRYLIC									
RESISTANCE:										
ABRASION	–	–	–	–	–	–	+	+	+	–
AGEING			–					+		
CHEMICALS		–				+		+		
FRICTION		–								
HEAT	+	+	–		+					
MILDEW	–	–		+		+	+		+	–
MOTHS	+	+	–	+		+	+	+	+	
PERSPIRATION	+	+	–	–			+	+	+	
PILLING		–				–	–	+		
STAINS								+	–	
SUNLIGHT	–	–	+	–		+	–	+	+	
WEATHER								+	–	
WRINKLING	–	–	+	+	–	+	+	–	+	+	–
SOFTNESS	+					+				–
STRENGTH										
WET	+			–	–	–	–	+		+	
DRY	+			+	–	–	–	+		+	
WARMTH			+				+			+	
WASH & WEAR										
QUALITY	–		–		–	+	+			+	–
WATER REPELLENCY			–							

SOURCE: "FIBERS AND FABRICS," BY J. M. BLANDFORD AND L. M. GUREL, CONSUMER GUIDE FROM THE NATIONAL BUREAU OF STANDARDS: GAITHERSBURG, MD 20760, 1970.

+ =GOOD TO EXCELLENT
– =FAIR TO POOR

FIGURE 1.8 (continued)

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FIGURE 1.9

APPROXIMATE CALORIC VALUES OF SOME COMMON FOODS

CALORIC VALUES ARE GIVEN IN NUMBERS THAT ARE MULTIPLES OF FIVE TO SIMPLIFY THE ESTIMATING OF TOTAL CALORIES.

FOOD	SIZE OF SERVING	APPROXIMATE CALORIES
FOODS CLASSED AS LARGELY CARBOHYDRATES:		
APPLES, RAW	1 MEDIUM	75
APPLE PIE	1/6 MEDIUM PIE	400
APPLE SAUCE	1/2 CUP	95
APRICOTS, CANNED	3-4 AND 2 T. JUICE	75
APRICOTS, FRESH	2-3	55
APRICOTS, DRIED	4-6 HALVES	100
ASPARAGUS, RAW	8-12 STALKS 5"	25
ASPARAGUS, CREAMED	1/4 CUP	100
BANANAS, FRESH	1 MEDIUM	100
BEANS, STRING, FRESH	1 CUP	25
BEETS, SLICED, FRESH	1 CUP	65
BISCUITS, BAKING POWDER	1 MEDIUM	100
BLACKBERRIES, FRESH	1/2 CUP	40
BLANC MANGE, CHOCOLATE	1/2 CUP	220
BLANC MANGE, PLAIN	1/2 CUP	150
BREAD, WHOLE WHEAT	1 SLICE, 1/2"	55
BREAD, WHITE ENRICHED	1 SLICE, 1/2"	60
BREAD, WHITE, RAISIN	1 SLICE, 1/2"	65
CABBAGE, RAW	1 1/4 CUP	30
CAKE, ANGEL	PIECE 3" CIRCUMFERENCE	140
CAKE, CUP, PLAIN	1 MEDIUM	200
CAKE, PLAIN	PIECE 2" X 1"	110
CAKE, SPONGE, HOT WATER	PIECE 3" CIRCUMFERENCE	155
CANTALOUPE	1/2 MEDIUM	45
CARBONATED BEVERAGES	6 OUNCES	80
CARROTS, RAW	2, 4" LONG	40
CARROTS, STEAMED, CUBED	1/2 CUP	20

CAULIFLOWER, STEAMED	1 CUP	30
CAULIFLOWER, RAW	1 CUP	25
CELERY	3/4 CUP OR 4 STALKS	20
CHERRIES, SOUR, FRESH, STONED	1 CUP	65
CHERRIES, SWEET, FRESH, STONED	1 CUP	65
CHOCOLATE, BITTER	1 SQUARE	140
CHOCOLATE CREAM MINT	1	50
CHOCOLATE FUDGE	PIECE 1 1/2" x 1" x 3/4"	100
COCOA, POWDERED	1 T.	20
COCONUT, PREPARED	1/3 CUP	115
CORN, CANNED	1/3 CUP	60
CORN, GREEN	1 MEDIUM EAR	85
CORN SYRUP	1/2 CUP	470
CORNFLAKES	1 CUP	50
CORNMEAL, COOKED	2/3 CUP	80
CORNMEAL, RAW	1/4 CUP	130
CORNSTARCH	1 T.	35
CRACKERS, GRAHAM	1	35
CRACKERS, SODA	1	30
CRANBERRY JELLY	2 T.	100
CREAM PIES WITH MERINGUE	1/6 MEDIUM PIE	300
CUCUMBER, FRESH	1/2 CUP OR 1 SMALL	15
DATES, UNSTONED	3-4	85
DOUGHNUTS	1	170
FIGS, DRIED	2 LARGE	100
FLOUR, WHEAT, WHITE, ENRICHED	1 CUP	405
FLOUR, WHOLE WHEAT	1 CUP	400
FRUIT COCKTAIL	3/8 CUP	100
GRAPEFRUIT	1/2 LARGE	100
GRAPENUTS	1/3 CUP	100
GRAPES, CONCORD, DELAWARE	SMALL BUNCH	80
GRAPES, MALAGA, TOKAY	SMALL BUNCH	75
GRIDDLE CAKES	1 CAKE 4" DIAMETER	80
HOMINY GRITS, COOKED	1 CUP	25
HONEY, STRAINED	1 T.	15
LEMON JUICE	1/2 CUP	10
LEMONS	1 MEDIUM	25
LETTUCE	1/4 LARGE HEAD	20

FIGURE 1.9 (continued)

MACARONI, COOKED	1/2 CUP	230
MAPLE SYRUP	1 T.	50
MINCE PIE	1/6 MEDIUM PIE	455
MUFFINS, PLAIN	1 MEDIUM	115
OATS, ROLLED, COOKED	2/3 CUP	100
ONIONS, RAW	1 SMALL OR 3 T.	10
ORANGE JUICE	1/2 CUP	55
ORANGES	1 MEDIUM	50
PARSNIPS, COOKED	1 MEDIUM OR 1 CUP	95
PEACHES, CANNED	1 HALVES, 3 T. JUICE	85
PEACHES, FRESH	1 MEDIUM	50
PEACHES, DRIED	4 MEDIUM HALVES	145
PEARS, CANNED	2 HALVES, 2 T. JUICE	80
PEARS, FRESH	1 MEDIUM	70
PEAS, CANNED	1/2 CUP	55
PEAS, DRIED, RAW	2 T.	85
PEAS, GREEN, SHELLED	3/4 CUP	75
PINEAPPLE, CANNED	1 SLICE, 3 T. JUICE OR 1 1/2 CUPS SHREDDED	90
PINEAPPLE, FRESH	1 CUP	74
POTATOES, SWEET, BAKED	1/2 MEDIUM	100
POTATOES, WHITE, RAW	1 MEDIUM	100
POTATOES, WHITE, CREAMED	1/2 CUP	150
PRUNES, DRIED	4 MEDIUM	75
PRUNES, STEWED	3 MEDIUM AND 2 T. JUICE	100
RAISINS, DRIED SEEDED	3/4 CUP	320
RASPBERRIES, FRESH	3/4 CUP	75
RHUBARB, FRESH	1 CUP	20
RICE, STEAMED	1 CUP	200
RICE PUDDING, CREAMY	1/2 CUP	110
ROLLS, YEAST	1 MEDIUM	120
SALAD, CHICKEN	1/2 CUP	235
SALAD, TOMATO, LETTUCE	1 SERVING	100
SAUCE, WHITE MEDIUM	1/4 CUP	110
SPINACH, COOKED	1/2 CUP	25
SQUASH, HUBBARD, COOKED	1/2 CUP	50
STRAWBERRIES, FRESH	3/4 CUP	40
SUGAR, BROWN	1 T.	50
SUGAR, GRANULATED	1 T.	50

SUGAR, POWDERED	1 T.	30
SUNDAE, VANILLA ICE CREAM WITH CHOCOLATE SAUCE	1/2 CUP	220
TAPIOCA, CREAM	1/2 CUP	190
TOMATO JUICE	1/2 CUP	25
TOMATOES, CANNED	1/2 CUP	25
TOMATOES, FRESH	1 MEDIUM	30
TURNIP GREENS, COOKED	1/2 CUP	20
TURNIPS, COOKED	1/2 CUP	20
WAFFLES	1, 6" DIAMETER	215
WATERMELON	PIECE 2 1/2" x 2" x 3"	85
WHEAT, SHREDDED	1 LARGE BISCUIT	100
YEAST, COMPRESSED	1 CAKE	25
FOODS CLASSED AS LARGELY PROTEIN:		
ALMONDS, CHOCOLATE	5	105
ALMONDS, SALTED	10-12	95
BEANS, BAKED	1/2 CUP	100
BEANS, LIMA, COOKED	1/3 CUP	100
BEANS, NAVY, COOKED	1/2 CUP	105
BEEF, HAMBURG STEAK, BROILED	CAKE, 2 1/3" DIAMETER, 1/2" THICK	120
BEEF, ROUND, BROILED	PIECE 2 1/2" x 3" x 1/2"	125
BEEF, SIRLOIN STEAK, LEAN, BROILED	PIECE 4" x 3" x 3/4"	350
BUTTERMILK	1 CUP	85
CHEESE, AMERICAN	1" CUBE	115
CHEESE, COTTAGE	1/3 CUP	75
CHICKEN, LEAN MEAT, COOKED	3 SLICES 3 1/2" x 2 1/2" x 1/4"	115
CHOCOLATE BEVERAGE MADE WITH MILK	3/4 CUP	210
EGGS, SCRAMBLED	1/2 CUP	180
EGGS, WHOLE	1	75
FISH, LEAN, BROILED	PIECE 4" x 2 1/4" x 2/3"	125
GELATIN, GRANULATED	1 T.	35
HAM, BAKED	PIECE 4" x 2 1/2" x 3/4"	280
HAM, BOILED	1 OZ.	85
ICE CREAM, VANILLA	1/3 CUP	150
JELLO	1/3 CUP	75
JUNKET, PLAIN	1/2 CUP	115

FIGURE 1.9 (continued)

LAMB CHOP, BROILED	1	250
LAMB ROAST	SLICE 3 1/2" x 4 1/2" x 1/8"	200
LIVER, RAW	PIECE 4" x 3" x 5/8"	130
MILK, SKIMMED	1 CUP	85
MILK, WHOLE	1 CUP	165
OYSTERS, RAW	1/3 CUP OR 3 1/2 LARGE	70
PORK CHOP, BROILED	1 MEDIUM	250
SALMON, CANNED	1/2 CUP	205
SODA WATER WITH VANILLA ICE CREAM	2/3 GLASS	200
SOUP, CREAM OF PEA	1/2 CUP	135
SOUP, CREAM OF TOMATO	1/2 CUP	125
WALNUTS, ENGLISH	10 MEATS OR 1 1/2 T. CHOPPED	100
FOODS CLASSED AS LARGELY FAT:		
BACON, COOKED	2 SLICES	100
BUTTER	1 T.	100
COD LIVER OIL	1 T.	100
COTTONSEED OIL	1 T.	125
CREAM, 40%	1/2 CUP	440
CREAM, 18%	1/2 CUP	245
FRENCH SALAD DRESSING	1/2 CUP	470
LARD	1 T.	125
MAYONNAISE DRESSING	1 T.	90
OLEOMARGARINE, FORTIFIED	1 T.	110
OLIVES, GREEN, UNSTONED	3-4	50
OLIVE OIL	1 T.	135
PEANUT BUTTER	1 T.	90
PEANUTS, SHELLED, ROASTED	9-10	50
RUSSIAN SALAD DRESSING	1 T.	100

The yardstick used to measure the energy that a food yields in the body is a calorie. The body uses this energy for bodily functions and exercise. If the diet contains more calories than the body can use for its purposes, it will store the extra energy as fat. One pound of fat is equal to 3500 calories. Add this number of calories to those you need to balance your energy requirements and you will gain one pound, substract it and you will lose a pound. Excess proteins, sugars, and carbohydrates, as well as fats can beconverted and stored as fat in the body.

Water is present in most foods and most body tissues and is essential to life and thermal comfort. Pure drinking water is necessary for health and is more palatable when cool than when warm. In warm climates and during heavy work, thirst develops more frequently than in cool climates and during sedentary work. Water is continuously lost from the body by evaporation, and for each gram of water evaporated there is a cooling effect of 640 calories equivalent to 1152 BTUs of water (8.3 gal.) per pound. Fifty-five percent of the cooling occurs through breathing out moist air. Total heat losses per day are between 640 and 1600 kilocalories (2540--6350 BTU) in normal adults, depending upon work level, activity, and environmental temperature.

Health can be maintained with proper clothing and diet over a wide range of outside temperatures, but is adversely affected by sudden onset of cold spells, prolonged cold wet periods, and by heat waves. During these periods, excessive deaths are usually caused by respiration diseases, influenza, and heat stroke, respectively. Indoors, health is maintained by even temperatures and avoidance of very humid and very dry conditions. Humid conditions, drafts, and uneven temperatures contribute to numerous infections from viruses and bacterial diseases. Very dry conditions contribute to dust production, coughing, and illness due to allergic conditions and the fact that the drying of mucous membranes in the nose and throat reduces normal disease resistance mechanisms in these tissues.

Discuss Figures 1.9 and 1.10 in relationship to your individual daily calorie intake and your daily activities. Are the two in balance? If not do you have a tendency to intake more calories than you require? Discuss solutions to this condition.

LECTURE

SUMMARY

Thermal energy in animals and humans is converted from food. This produces heat. Heat loss and heat gain must be controlled in order for a human or animal to maintain comfort and survival. This heat control must be accomplished through food and water intake, clothing, activity, and maintaining healthful indoor conditions.

LABORATORY

Have students keep a listing of food consumed during one week. Using the calorie table at Figure 1.9. Calculate the daily calorie intake. Break down each meal into the number of carbohydrates, proteins, and fats consumed. Are there any differences in the quantity or type of food consumed on days where heavy physical activity occurs versus a day of less strenuous activity?

HUMAN COMFORT AND ENERGY CONSERVATION

UNIT 2: How Natural Climates and Artificial Environments are Defined

Goal Statement:

This lesson discusses the effects of air temperature, humidity, and wind speed on the human body and skin temperature, and the changes in heat balance produced by air movement, humidity, and seasonal weather conditions. On completion, the student will know characteristic climates of Texas cities and how these are plotted on a comfort chart.

LECTURE	LABORATORY

UNIT 2:

a. Characteristics of Hot and Cold Air

For still air at a fixed mid-humidity level, the air feels warm when the dry bulb temperature (T_{DB}) is higher than skin temperature (T_{SK}), and air feels cold when T_{DB} is lower than T_{SK}. air movement cools the body by increasing heat losses or evaporative cooling thus producing comfort index changes. The sensations of heat and cold are magnified when air movement is high, and when nearby surface temperatures, T_{surf}, such as windows, glass, walls, floors, and ceiling, are significantly higher or lower than comfortable T_{DB}, because of radiation and connective cooling or heating, radiative heating being more readily experienced. The difference in comfort depends primarily upon the difference between T_{DB} and T_{SK}, in addition to clothing, activity level, air movement, and humidity. T_{surf} is replaced by sky temperatures, solar radiation, and ground and wall temperatures in the outdoors.

Discuss the Figure 2.1:

FIGURE 2.1

MAXIMUM AND MINIMUM TEMPERATURES

Mean Temperature*	max. F	min. F	range F
TSK (comfort)	95	91	4
TDB (comfort)	93	72	19
TSK (outdoors)	100	75	25
TDB (outdoors-Texas)	98	20	78
TDB (outdoors-Continental USA)	105	-3	108
T(surf) (outdoors-** Texas)	139	6	133
T(surf) (outdoors-** Continental USA)	168	NA	NA

*Individual reactions to temperature may vary substantially. The mean TSK is usually the average skin temperature for feet, lower and upper leg, trunk, arms, hands and head. However, the feet and leg temperatures and usually much more variable than the trunk and head TSK. Outdoor TDB are average monthly air temperatures for July and January (max. °F and min. °F, respectively). Mean T(surf) outdoors is the mean of shade and exposed ground temperatures and sky temperature and surface temperature of nearby objects.

** Estimatd 1-hour averages on light surfaces. Computer models for dark surfaces predict occasional values as high as 198 F for one hour.

It is clear that the average change in T_{DB} for staying in the comfort zone is much smaller in range than long term monthly range of average outdoor temperatures. It is also clear that T_{SK} for comfort is rather narrow in range. Maximum and minimum temperature can be measured using either a maximum-minimum thermometer, or a thermograph.

Mount maximum-minimum thermometers side-by-side with thermographs for a 24 hour period: (a) outdoors, (b) in a non-air conditioned buildings, and (c) in an air conditioned space. Note that the maximum- minimum thermometers record only the highest and lowest temperature (T_{DB}) in the 24 hour period. By contrast the thermographs give two additional items of information: (1) when these temperatures were achieved, and (2) how long the temperatures remained above or below any desired temperature range (i.e., T_{SK}). Is there much difference between (a), (b) and (c)? Why?

UNIT 2:

b. Air Movement and Humidity

Both velocity of air movement, or windspeed ($V\text{-}_{air}$), and wet bulb temperature (T_{WB}) affect human comfort. The V-air is measured with a vane gauge anemometer and produced by a fan, wind, or natural ventilation. The T_{WB} is measured with a regular thermometer whose bulb is covered by a moist, loosely knit wick or cover, and exposed to air movement.

Mount a vane gauge anemometer and a sling psychrometer (commonly called a wet-and-dry bulb psychrometer) in front of a moving fan. Also place two beakers of hot water nearby --one should be covered with a lid and the other should be open. Run the fan for one hour and take temperature readings periodically. Verify the table in Figure 2.2.

FIGURE 2.2

EXPERIMENT

TIME	TDB	CLOSED CONTAINER	TWB	OPEN CONTAINER
BEFORE STARTING FAN	SAME AS AIR TEMPERATURE	HOT (T HOT)	SAME AS AIR TEMPERATURE	HOT (T HOT)
AFTER 5 MINUTES	AS ABOVE	STILL HOT	DROPS	SOMEWHAT COOLER
AFTER 30 MINUTES	AS ABOVE	SOMEWHAT COOLER	NO FURTHER CHANGE*	COOLER THAN CLOSED CONTAINER
AFTER 60 MINUTES	AS ABOVE		NO FURTHER CHANGE*	MUCH COOLER

*IF THE WICK IS ALLOWED TO GO DRY, NOTE THAT TWB WILL RISE UNTIL TWB = TDB. CONFIRM THIS. KEEP THE WICK MOIST FOR ACCURATE TWB READINGS.

LECTURE	LABORATORY

Air movement produces cooling of both closed and open containers from T_{Hot}) towards T_{DB}. If the surroundings air is humid, T_{WB} will drop only two or three degrees. If the surroundings air is dry, T_{WB} will drop four to six degrees or more. The difference between T_{DB} and T_{WB} (= T_{DB} minus T_{WB}) is called the <u>evaporative cooling</u> effect, and can be used to measure air humidity.

The rate of temperature drop of surface to value ratio for the two water filled containers will depend on their size, or V-air, and/or T_{Hot}), T_{DB}, T_{WB}. Cooling will be slow if the containers are large and completely filled, and if T_{Hot}) is substantially greater than T_{DB} and T_{WB}. Cooling will be rapid if the containers are small or underfilled, and if the containers are small or underfilled, and if T_{Hot}) is only a few degrees above T_{DB} and T_{WB}. The closed container will cool due to passage of cool air over warm surface or <u>convective cooling</u>. The open container will cool due to combined convective cooling and evaporative cooling. The combined effect is greater than either effect measured singly. The rate of evaporative cooling increases with temperature for dry air, but the rate of convertive cooling decreases.

Discuss conventive cooling and evaporative cooling in relation to student experience at the swimming pool:

(a) on removal of top clothing
(b) on climbing out of the pool--still day
(c) on climbing out of the pool--windy day
(d) on sitting in wet swim suits
(e) on sitting in wet clothing
(f) on changing from wet to dry clothing.

Is there any difference between the hot, wet conditions of a coastal city such as Houston or Galveston, and the hot, dry conditions of El Paso or Midland in summer?

UNIT 2:

c. <u>Natural Outdoor Conditions vs Season and Geography</u>

Residentially acclimatized persons form distinct groups in regard to their comfort. Persons residing in the tropics between latitudes 23.5°N and 23.5°S are typically acclimatized to comfort between 65° and 100°F. Persons residing in temperate zones between latitudes 23.5° and 66.1°N an S are typically acclimatized to comfort between 53° and 93°F.

A temperature/humidity comfort chart at Figure 2.3 shows the relationship between T_{DB} and humidity (grams of water per kilogram of air) with relative saturation between 10% and 100%.

Residents of Texas fall in a bell-shaped intermediate sub-topical zone between the two shaded areas on the chart in Figure 2.3.

Neither summer nor winter temperatures are uniform with regard to degrees of latitude, as shown by the January and July surface temperatures isotherm maps in Figure 2.4. The upper map contains lines drawn to connect all points with average January temperatures of 20°C (68°F), 10°C (50°F), 0°C (32°F), -10°C (140 °F), and so on. These are the so-called isotherms, or places of equal average temperature. Latitude, longitude, altitude , and natural atsmophere flow patterns determine local climatology.

Study the world isotherm map for the coldest month in the Northern Hemisphere (January). Locate Texas. Between what two temperatures does the monthly average lie? Discuss.

Study the world isotherm map for the warmest month in the Northern Hemisphere (July). Locate East Texas and West Texas. Is there a difference between their monthly average temperature? Discuss.

TEMPERATURE - HUMIDITY - COMFORT RELATIONSHIPS

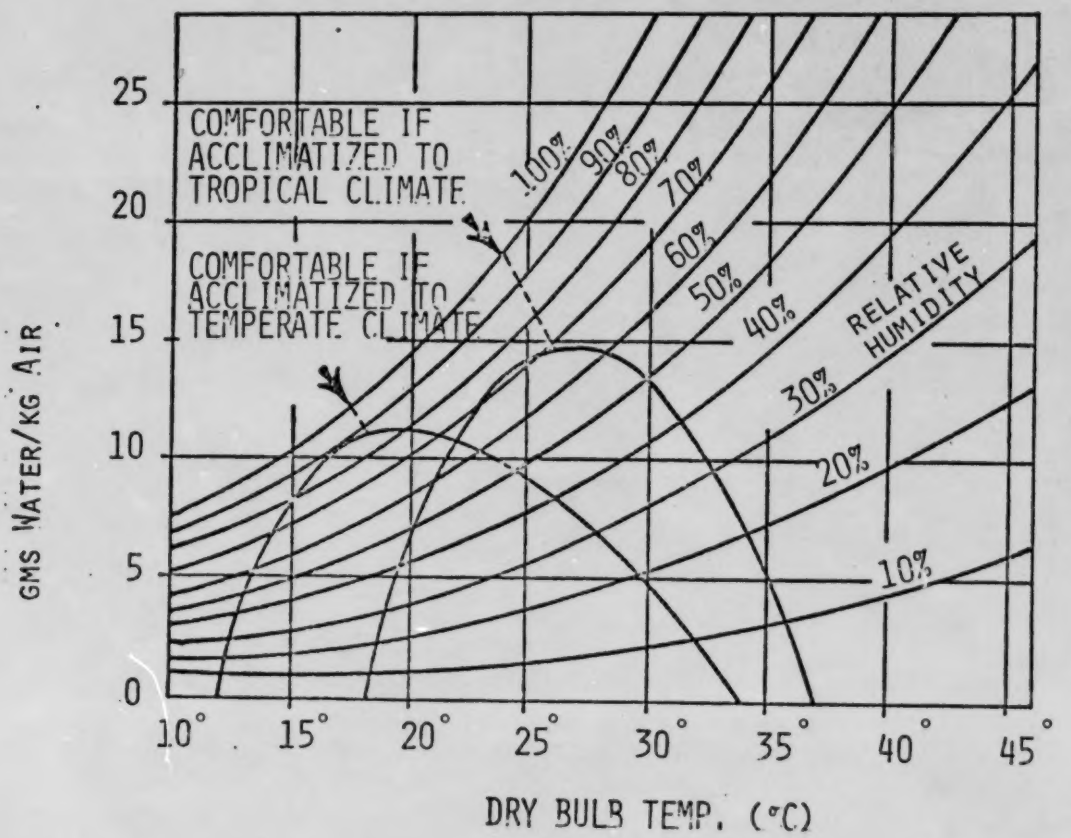
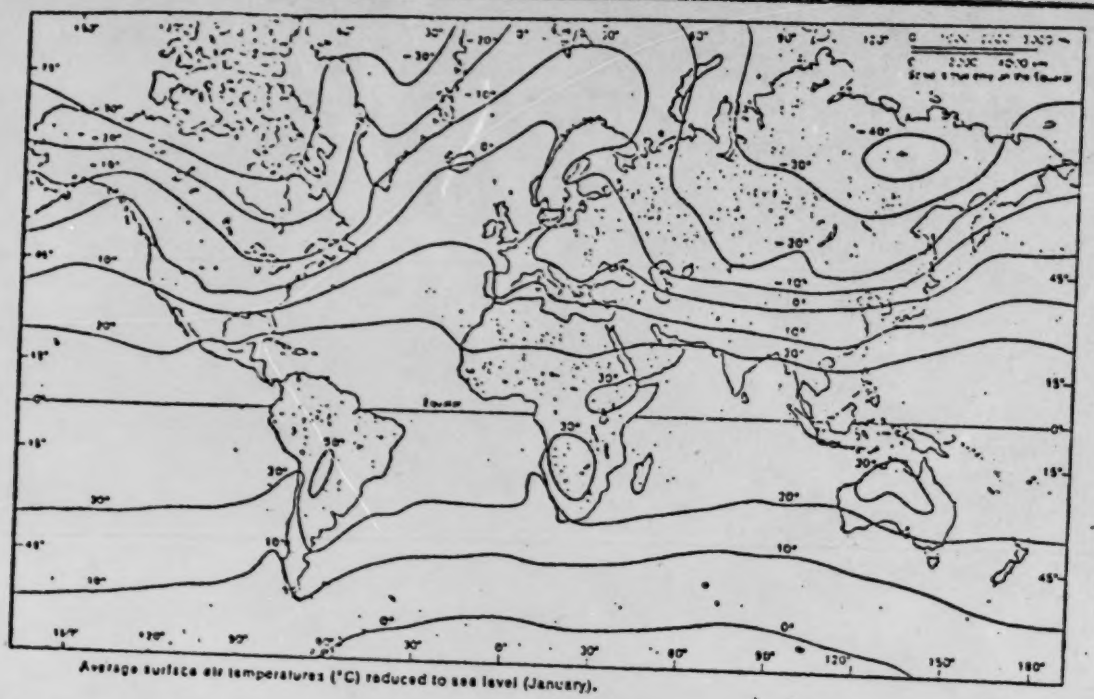
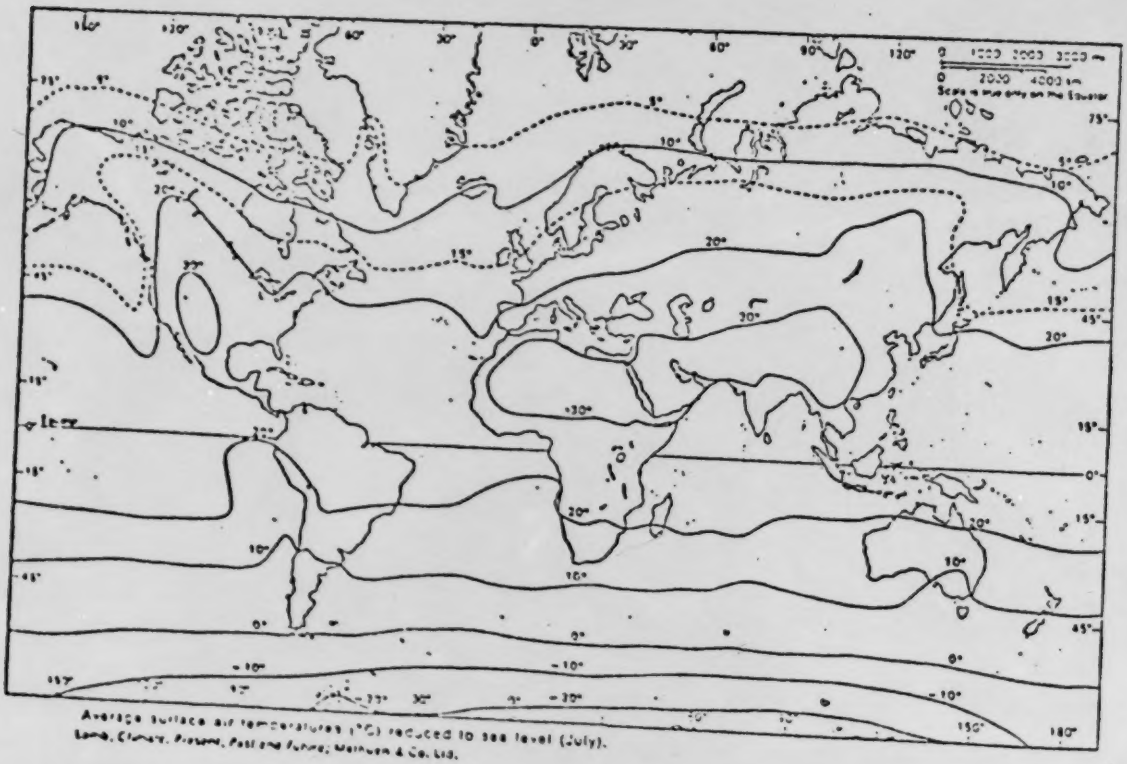


FIGURE 2.3

FIGURE 2.4 - WORLD ISOTHERM MAPS - JANUARY AND JULY



Average surface air temperatures (°C) reduced to sea level (January).



Average surface air temperatures (°C) reduced to sea level (July).
Lamb, Climate, Present, Past and Future, Methuen & Co. Ltd.

LECTURE

The lower map provides July isotherms. Texas is intersected by the July 30°C (86°F) isotherm, showing that the western section is among the hotter areas of the world in summer when reduced to sea level equivalents. The Figure 2.5 gives record and average July highs and January lows for 42 Texas cities.

LABORATORY

Plot the temperature and preciptation as a function of month for your home, city or nearest one listed at Figure 2.5.

On the same graph, also plot temperate and humidity for:

Houston
El Paso
Amarillo

Note the differences and explain reasons for these.

FIGURE 2.5

CLIMATOLOGICAL AVERAGES AND EXTREMES

	TEMPERATURE(°F)				PRECIPITATION (INCHES)												
	A	B	C	D	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
ABILENE	94	33	111	- 9	.88	1.09	1.04	2.27	4.33	2.67	2.28	1.47	2.07	2.85	1.11	1.26	23.32
AMARILLO	92	21	108	-16	.65	.62	.82	1.32	3.37	2.89	2.34	2.58	1.89	1.76	.66	.77	19.67
ANGLETON	91	46	105	10	3.63	3.84	3.18	3.20	3.90	3.51	5.53	4.82	5.44	3.80	3.70	4.61	49.16
AUSTIN	95	41	109	- 2	2.35	2.58	2.13	3.55	3.71	3.22	2.18	1.94	3.44	2.83	2.12	2.53	32.58
BAY CITY	93	43	106	11	3.00	3.03	2.17	2.91	4.32	4.20	3.34	4.83	5.83	3.65	3.09	3.47	43.84
BEAUMONT	93	44	108	4	4.57	4.38	2.82	4.43	4.79	4.75	5.71	5.34	5.30	3.19	4.54	4.95	54.77
BEEVILLE	95	45	111	5	2.08	1.76	1.78	2.44	3.24	2.99	2.87	2.20	3.64	2.48	1.90	2.23	29.61
BRENHAM	95	43	111	- 2	3.22	3.11	2.74	3.58	4.18	3.29	2.88	2.88	2.88	2.86	3.81	3.89	39.12
BROWNSVILLE	93	52	104	12	1.36	1.31	1.07	1.37	2.55	2.63	1.73	2.54	5.51	3.22	1.78	1.55	26.65
CLEBURNE	96	35	114	- 3	2.04	2.64	2.35	3.79	4.46	2.92	2.17	2.25	2.78	2.94	2.28	2.58	33.20
CORPUS CHRISTI	94	47	105	11	1.63	1.70	1.44	2.14	2.99	2.39	2.32	2.77	4.40	2.76	1.72	2.08	28.34
CORSICANA	96	36	113	- 7	2.86	3.00	2.88	4.32	4.98	3.12	1.90	2.19	2.67	2.96	2.97	3.21	37.06
DALLAS	95	36	111	- 3	2.32	2.55	2.85	4.00	4.83	3.24	1.94	1.93	2.82	2.70	2.70	2.67	34.55
DENISON DAM	95	31	109	2	1.62	2.62	2.53	4.65	4.77	3.88	2.81	2.49	3.92	2.81	2.55	2.22	36.87
DENTON	96	34	113	- 3	1.90	2.42	2.51	3.69	5.03	3.16	2.05	1.73	2.37	2.46	2.05	2.19	31.56
DUMAS	93	20	109	-18	.60	.54	.78	1.30	2.95	2.45	2.60	2.62	1.55	1.60	.64	.70	18.33
EL PASO	94	32	109	- 8	.46	.41	.35	.29	.40	.69	1.29	1.19	1.14	.85	.33	.49	7.89
FORT WORTH	96	35	112	- 8	2.04	2.24	2.51	3.60	4.59	2.98	1.75	1.68	2.54	2.59	2.46	2.35	31.33
GAINESVILLE	96	32	114	-12	2.07	2.51	2.64	3.75	5.09	3.79	2.38	2.45	2.63	2.91	2.09	2.23	34.54
GALVESTON	87	42	101	8	3.46	2.88	2.86	2.59	2.79	2.65	4.79	4.39	5.09	2.86	3.56	3.89	41.81
GONZALES	96	42	106	18	2.15	2.32	1.96	3.55	3.71	2.91	2.79	2.43	3.54	2.42	2.42	2.53	32.73
GREENVILLE	94	34	116	- 4	2.89	3.31	3.56	4.75	5.72	4.20	3.18	2.27	2.92	3.21	3.54	3.26	42.81
HOUSTON	93	45	109	5	3.78	3.44	2.67	3.24	4.32	3.69	4.29	4.27	4.26	3.77	3.86	4.36	45.95
KERRVILLE	94	34	110	- 7	1.86	2.07	2.02	3.07	4.19	2.99	2.32	1.85	4.22	3.14	1.52	2.25	31.50
KINGSVILLE	96	48	108	11	1.65	1.50	1.30	2.05	3.00	2.30	2.00	2.50	4.75	2.45	1.38	1.62	26.50
LUBBOCK	92	25	107	-16	.68	.57	.73	1.15	3.18	2.53	2.01	1.68	2.36	2.00	.54	.65	18.08
MARSHALL	95	37	112	- 9	4.75	4.01	4.40	4.43	5.25	3.18	3.28	2.53	2.70	3.01	4.41	5.01	46.96
McALLEN	96	48	106	17	1.18	1.03	.66	1.56	2.19	2.36	.88	1.84	3.69	2.58	.98	.84	19.79
McKINNEY	96	34	118	- 7	2.21	2.59	2.78	3.97	5.28	3.22	2.42	1.78	2.82	2.95	2.61	2.17	34.80
MEMPHIS	98	26	117	-11	.76	.77	.89	1.76	4.28	2.78	1.84	1.62	2.07	2.01	.50	.63	19.91
MIDLAND	95	31	109	-11	.80	.60	.36	.83	2.08	1.63	1.88	1.48	1.79	1.66	.47	.66	14.24
MULESHOE	92	20	110	-21	.65	.48	.62	1.02	2.80	2.48	2.37	2.21	1.99	1.62	.55	.65	17.44
PAMPA	94	23	109	-12	.53	.69	.79	1.50	3.62	3.00	2.48	2.39	1.91	1.83	.61	.81	20.16
PARIS	94	34	115	-13	3.08	3.45	3.47	5.19	5.40	4.26	3.65	2.73	3.52	3.22	3.78	3.36	45.11
PLAINVIEW	93	26	108	- 8	.80	.62	.68	1.53	3.18	2.58	2.47	2.05	2.02	1.64	.59	.82	18.96
PORT ARTHUR	91	44	107	11	4.23	4.45	3.44	3.94	4.94	4.29	6.00	5.49	4.88	2.88	3.46	5.09	53.09
SAN ANTONIO	94	42	107	0	1.74	1.65	1.67	2.82	3.45	2.95	2.09	2.36	3.49	2.50	1.37	1.75	27.84
TYLER	94	37	106	- 8	3.98	3.67	3.91	4.89	5.45	3.27	3.26	2.91	2.74	3.23	4.21	4.77	46.19
VICTORIA	92	46	110	9	2.34	2.34	2.32	2.62	4.12	3.04	3.61	3.13	4.23	3.45	2.36	2.61	36.20
WACO	96	38	112	- 5	2.27	2.42	2.35	3.88	4.57	2.67	1.99	1.66	2.77	2.55	2.19	2.74	32.08
WEATHERFORD	96	34	113	-11	2.14	2.46	2.16	3.58	5.39	3.00	1.80	1.67	2.70	3.04	1.82	2.12	31.37
WICHITA FALLS	97	31	113	-12	1.12	1.38	1.54	2.53	4.60	3.20	1.97	1.79	2.33	2.87	1.42	1.45	26.20

A - Average July Temperature
B - Average January Temperature
C - Record Highest
D - Record Lowest

NOTE: Data compiled through 1974 except where noted otherwise:
1 - Period of Record, 1943-1973
2 - Period of Record, 1937-1967
3 - Period of Record, 1934-1970
4 - Period of Record, 1940-1967
5 - Period of Record, 1942-1973

Humidity depends upon average precipitation, time since last rainfall, wind direction, windspeed, time of day, and cloud cover. A full climatological table gives monthly and yearly temperatures, degree-days of heating and cooling, relative humidity, percipitation, wind speed and direction, days of sunshine, cloud cover, precipitation, thunder, and fog. Examples for six Texas cities are at Figure 2.6, and each National Weather Station publishes monthly and annual climatological data for its location.

FIGURE 2.6 - CLIMATOLOGY OF SIX TEXAS CITIES

BROWNSVILLE — Elevation 19 FT.

	Temperature Average Maximum	Temperature Average Minimum	Temperature Average Monthly	Temperature Extreme Highest	Temperature Extreme Lowest	Degree Days (Base 65°) Heating	Degree Days (Base 65°) Cooling	Rel. Hum 12:00 p.m.	Prec. Nor. Total	Prec. Nor. Snow Total	Wind Speed	Wind Direction	Average Number of Days of Sunup/Sundown % Poss. Sunshine	Clr.	P.C.	Cldy.	Rain .01"	Snow 1.0"	Thunder	Fog	Percent IFR
J	71	51	61	85	33	295	105	85	1	T	11	22	65	7	7	17	7	0	1	3	14
F	73	53	63	86	33	206	142	80	1	T	11	22	66	6	6	15	6	0	1	3	14
M	77	57	67	91	35	76	266	74	1	T	11	22	67	8	11	12	4	0	1	3	14
A	82	66	74	96	48	8	354	68	1	T	10	22	70	8	11	11	4	0	0	1	4
M	89	73	81	98	57	0	524	68	3	0	10	22	72	9	15	7	5	0	3	3	9
J	91	74	83	101	67	0	620	68	2	0	10	22	73	8	13	9	5	0	3	1	6
J	93	74	84	105	69	0	705	68	1	0	10	22	73	8	14	9	4	0	3	*	3
A	93	75	84	105	69	0	705	67	1	0	10	22	73	8	14	9	4	0	3	*	3
S	93	73	83	103	63	0	654	67	2	0	10	22	73	8	13	9	5	0	3	*	4
O	86	67	76	97	54	11	376	70	3	0	10	22	71	11	12	8	6	0	4	*	5
N	78	57	67	92	38	111	153	80	2	0	10	22	68	12	8	10	5	0	2	*	3
D	73	53	63	88	34	206	143	83	2	T	11	22	66	11	7	13	5	0	1	*	4
Y	83	65	74	100	33	800	4200	69	19	1	12	22	69	97	128	133	71	0	33	26	8

DEL RIO — Elevation 1026 FT.

	Temperature Average Maximum	Temperature Average Minimum	Temperature Average Monthly	Temperature Extreme Highest	Temperature Extreme Lowest	Degree Days (Base 65°) Heating	Degree Days (Base 65°) Cooling	Rel. Hum 12:00 p.m.	Prec. Nor. Total	Prec. Nor. Snow Total	Wind Speed	Wind Direction	Average Number of Days of Sunup/Sundown % Poss. Sunshine	Clr.	P.C.	Cldy.	Rain .01"	Snow 1.0"	Thunder	Fog
J	64	39	51	89	18	439	10	58	1	T	10	26	62	11	8	14	4	0	0	2
F	69	43	56	88	21	358	18	52	1	T	10	26	63	10	9	13	5	0	1	4
M	77	49	63	101	25	147	114	49	1	T	11	26	63	11	8	12	4	*	1	2
A	85	59	72	102	38	18	196	53	1	T	10	26	63	7	7	16	3	0	0	1
M	91	68	78	103	45	0	421	57	3	0	11	26	63	8	9	14	5	0	0	1
J	97	72	84	105	55	0	661	58	2	0	12	26	63	6	14	10	4	0	0	*
J	99	74	86	108	66	0	834	60	1	0	11	26	63	13	12	6	3	0	0	*
A	98	74	86	109	64	0	829	53	1	0	10	26	63	10	12	9	5	0	0	*
S	92	68	80	103	48	0	622	53	3	0	9	26	63	9	11	10	5	0	0	*
O	83	59	71	94	36	31	201	57	2	T	9	26	63	12	8	11	4	0	0	1
N	71	45	58	91	25	218	43	67	1	0	8	26	63	11	7	12	4	0	0	1
D	65	40	52	84	23	334	8	56	1	T	8	26	62	11	5	15	3	0	1	2
Y	83	57	70	109	18	1504	3859	54	18	1	10	26	63	117	104	144	53	*	35	16

CORPUS CHRISTI — Elevation 41 FT.

	Temperature Average Maximum	Temperature Average Minimum	Temperature Average Monthly	Temperature Extreme Highest	Temperature Extreme Lowest	Degree Days (Base 65°) Heating	Degree Days (Base 65°) Cooling	Rel. Hum 12:00 p.m.	Prec. Nor. Total	Prec. Nor. Snow Total	Wind Speed	Wind Direction	Average Number of Days of Sunup/Sundown % Poss. Sunshine	Clr.	P.C.	Cldy.	Rain .01"	Snow 1.0"	Thunder	Fog
J	71	49	60	87	25	281	78	78	2	T	11	22	62	9	8	14	5	0	0	3
F	73	51	62	88	28	206	102	77	2	T	11	22	63	8	7	13	5	0	0	3
M	77	57	67	91	33	102	178	74	2	T	11	22	64	8	9	14	5	0	0	3
A	82	63	72	96	47	21	327	70	2	T	10	22	67	9	11	10	4	0	0	2
M	86	69	78	98	57	0	463	72	3	0	10	22	69	8	13	10	5	0	0	2
J	89	73	81	101	67	0	597	72	3	0	10	22	70	8	12	10	5	0	0	2
J	91	74	83	103	69	0	705	72	2	0	10	22	71	8	13	9	4	0	0	2
A	91	74	83	103	69	0	705	72	2	0	10	22	71	8	13	9	4	0	0	2
S	88	72	80	101	63	0	588	73	3	0	10	22	71	8	12	10	5	0	0	3
O	82	66	74	96	52	11	327	75	3	0	10	22	70	11	11	9	5	0	0	3
N	74	54	64	92	33	129	127	77	2	T	10	22	66	12	9	9	4	0	0	3
D	69	47	58	85	25	259	114	77	2	T	10	22	63	13	8	10	4	0	0	3
Y	81	63	72	101	25	914	2895	74	28	1	10	22	68	84	104	122	109	39	*	31	28

SAN ANTONIO — Elevation 788 FT.

	Temperature Average Maximum	Temperature Average Minimum	Temperature Average Monthly	Temperature Extreme Highest	Temperature Extreme Lowest	Degree Days (Base 65°) Heating	Degree Days (Base 65°) Cooling	Rel. Hum 12:00 p.m.	Prec. Nor. Total	Prec. Nor. Snow Total	Wind Speed	Wind Direction	Average Number of Days of Sunup/Sundown % Poss. Sunshine	Clr.	P.C.	Cldy.	Rain .01"	Snow 1.0"	Thunder	Fog
J	62	42	52	89	6	428	14	68	2	T	10	22	62	9	8	14	5	0	0	3
F	66	45	55	92	6	295	26	67	2	T	10	22	63	8	8	12	5	0	0	3
M	72	50	61	100	21	195	120	63	2	T	11	22	65	8	8	15	5	0	0	3
A	79	58	69	99	34	59	199	56	3	0	11	22	68	7	8	15	7	0	0	3
M	85	65	75	101	44	0	414	57	3	0	10	22	68	7	11	13	7	0	0	3
J	92	72	82	103	53	0	554	54	3	0	10	22	68	7	16	7	6	0	0	4
J	94	74	84	106	67	0	658	49	3	0	9	22	68	10	15	5	4	0	0	4
A	94	73	84	105	61	0	609	49	3	0	9	22	68	11	14	6	5	0	0	4
S	89	69	79	102	41	0	459	54	3	0	8	22	68	10	12	8	5	0	0	4
O	82	60	71	95	33	31	281	53	3	0	8	22	67	12	10	9	5	0	0	3
N	70	49	60	91	23	204	81	54	1	0	8	22	67	11	7	12	4	0	0	2
D	65	42	54	90	14	363	31	58	2	T	8	22	62	10	6	15	3	0	0	2
Y	79	58	69	106	6	1546	3368	54	26	1	9	22	65	110	119	136	59	*	35	23

DALLAS — Elevation 481 FT.

	Temperature Average Maximum	Temperature Average Minimum	Temperature Average Monthly	Temperature Extreme Highest	Temperature Extreme Lowest	Degree Days (Base 65°) Heating	Degree Days (Base 65°) Cooling	Rel. Hum 12:00 p.m.	Prec. Nor. Total	Prec. Nor. Snow Total	Wind Speed	Wind Direction	Average Number of Days of Sunup/Sundown % Poss. Sunshine	Clr.	P.C.	Cldy.	Rain .01"	Snow 1.0"	Thunder	Fog	Percent IFR
J	56	34	45	88	0	691	0	68	2	T	11	22	62	9	7	15	5	0	0	3	11
F	61	36	49	88	0	555	0	66	2	T	11	22	63	8	6	14	5	0	0	3	11
M	69	45	57	94	15	335	0	63	3	T	11	22	65	8	8	15	6	0	0	3	11
A	78	56	67	98	28	88	0	61	3	T	10	22	68	8	9	13	6	0	0	3	10
M	86	66	76	101	46	0	0	63	4	0	10	22	68	8	11	12	6	0	0	3	10
J	93	73	83	105	59	0	0	63	3	0	10	22	68	8	12	10	5	0	0	3	10
J	96	75	86	108	66	0	0	63	2	0	10	22	68	8	13	9	4	0	0	3	10
A	96	75	86	108	66	0	0	63	2	0	10	22	68	8	13	9	4	0	0	3	10
S	91	72	82	104	59	0	0	63	3	0	10	22	68	8	12	10	5	0	0	3	10
O	84	62	73	97	43	0	0	63	3	0	10	22	68	11	11	9	5	0	0	3	10
N	73	52	62	92	27	159	0	64	3	0	10	22	67	12	9	9	4	0	0	3	10
D	67	46	57	88	23	270	0	68	3	0	10	22	63	13	8	10	4	0	0	3	10
Y	79	61	70	108	16	1773	3330	64	36	1	10	22	66	82	125	158	62	0	0	36	10

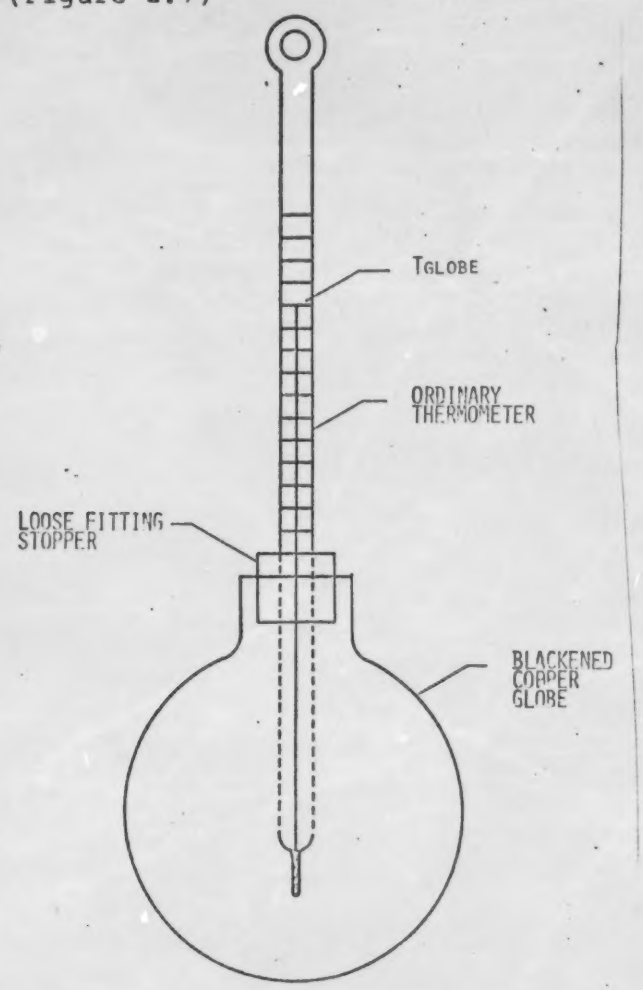
VICTORIA — Elevation 104 FT.

	Temperature Average Maximum	Temperature Average Minimum	Temperature Average Monthly	Temperature Extreme Highest	Temperature Extreme Lowest	Degree Days (Base 65°) Heating	Degree Days (Base 65°) Cooling	Rel. Hum 12:00 p.m.	Prec. Nor. Total	Prec. Nor. Snow Total	Wind Speed	Wind Direction	Average Number of Days of Sunup/Sundown % Poss. Sunshine	Clr.	P.C.	Cldy.	Rain .01"	Snow 1.0"	Thunder	Fog
J	65	48	55	88	16	344	70	64	3	T	11	22	62	7	7	17	8	0	0	3
F	67	49	58	90	22	320	35	59	3	T	11	22	63	8	5	15	7	0	0	3
M	73	54	63	95	28	157	104	57	3	T	12	22	65	6	8	15	7	0	0	3
A	79	61	70	99	36	91	172	60	3	0	12	22	68	4	11	15	7	0	0	3
M	85	68	76	101	45	0	300	60	3	0	11	22	68	4	12	15	7	0	0	3
J	93	73	83	104	62	0	540	58	3	0	10	22	68	6	15	9	6	0	0	3
J	93	74	83	107	63	0	633	55	3	0	9	22	68	7	15	8	6	0	0	3
A	92	74	83	107	63	0	633	54	3	0	9	22	68	7	15	9	6	0	0	3
S	88	71	79	99	51	0	459	61	3	0	9	22	68	7	13	10	6	0	0	3
O	83	62	73	95	38	4	303	55	3	0	9	22	68	10	12	9	6	0	0	3
N	73	52	62	92	27	159	74	56	3	0	9	22	67	12	8	10	5	0	0	3
D	67	48	57	88	23	270	58	63	3	0	9	22	63	13	8	10	5	0	0	3
Y	79	61	70	107	16	1773	3330	59	36	1	10	22	66	82	125	158	82	0	0	43

UNIT 2:

d. How Human Comfort Zones are Measured

Human comfort zones are measured in several different ways, but all rely on T_{DB}, T_{WB}, and $V\text{-}_{air}$. In high temperature surroundings or intense sunshine T_{globe} replaces T_{DB}. T_{gobe} is the black globe thermometer temperature, measured at the center of a six inch diameter copper sphere with a matt black absorbent surface for heat. T_{globe} describes the combined physical effect of T_{DB}, $V\text{-}_{air}$, and radiant heat, and measures average radiant temperature. (Figure 2.7)



GLOBE THERMOMETER FOR DETERMINING MEAN RADIANT TEMPERATURE

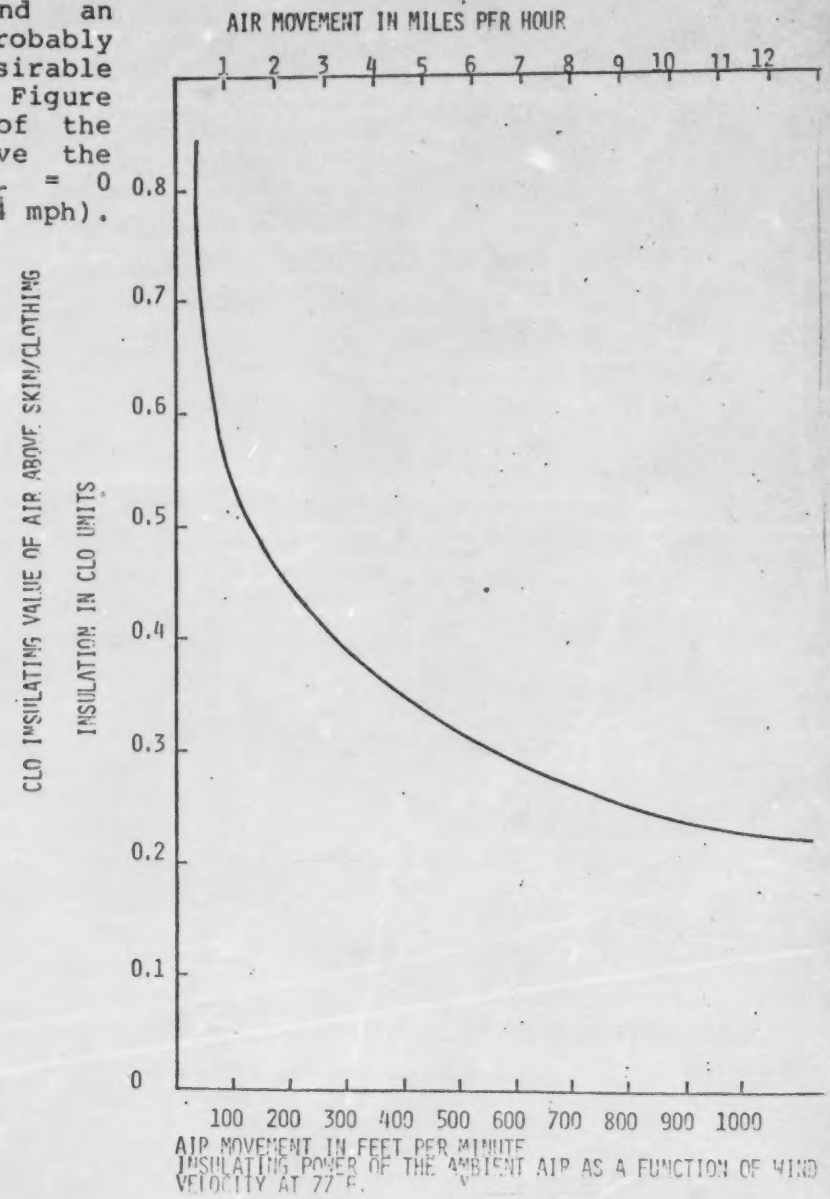
FIGURE 2.7

$V\text{-}_{Air}$ Graph

Measure T_{DB}, T_{WB}, $V\text{-}_{air}$ in the laboratory and outside at the present time using a sling psychrometer and vane gauge anemometer. Locate both $V\text{-}_{air}$ values on the graph. The study of radiant effects is complex. The mean radiant temperature in an enclosed space is the mean of all the surfaces bounding the space in proportion to their areas and temperatures. The effect of a large areas of window, which may be cold in winter and hot in summer, produces variations in different parts of a room. Moreover, the body itself is sizable, and its response varies according to differences of clothing. These effects are measured by T_{globe}, including such changes as are caused by introducing heated surfaces to warm the space and by the entrance of heat through windows via sunshine.

Use comfort zone chart at Figure 2.3. Show how one's comfort index value changes with changes in temperature, humidity, and wind speed.

In warm indoor environments, air movement is important to comfort because (a) it allows evaporative cooling, and (b) it removes the insulating layer of still air above skin and clothing. Moderate air movements (V_{air} = 200-400 feet per unit; 2-1/4 - 4-1/2 mph) are effective in ventilating the body surface for comfort and increase body cooling in the range 77°-95°F. Above 400 feet per minute, there is a tendency to disturb papers and dust. At V_{air} 200 feet-per-minute air movement, there is progressively less convective cooling and an increasing sense of warmth, probably desirable below 77°F and undesirable above 77°F. The diagram at Figure 2.8 shows the "clo" value of the insulating layer of air above the skin and clothing for V_{air} = 0 to 1000 feet per minute (0-11.4 mph).



INSULATING POWER OF THE AMBIENT AIR AS A FUNCTION OF WIND VELOCITY AT 77°F.

FIGURE 2.8

This is the basis for the use of ceiling fans and large pedestal fans in producing comfort in warm surroundings.

In the temperature range 65°F to 77°F, both indoors and outdoors, T_{DB} and T_{WB} are both important, and a range of 20-60% relative humidity (RH) is preferred for comfort. Above 60% HR, air begins to feel moist and evaporative cooling becomes less effective, while above 85% RH there is a feeling of humid discomfort on the skin and under clothing. Below 20%, air feels dry, thus skin tends to dry, shink, and occasionally crack.

Verify that 20% RH, 60% RH, 65°F, 72°F and 77°F have been plotted correctly on the T_{DB}/T_{WB} chart at figure 2.9. On the chart, can you write in the summer and winter T_{DB} and T_{WB} for any selected Texas city, using the table at Figure 2.10?

Does Figure 2.10 now tell you why summer air cooling is important in Texas? To what extent is winter heating important?

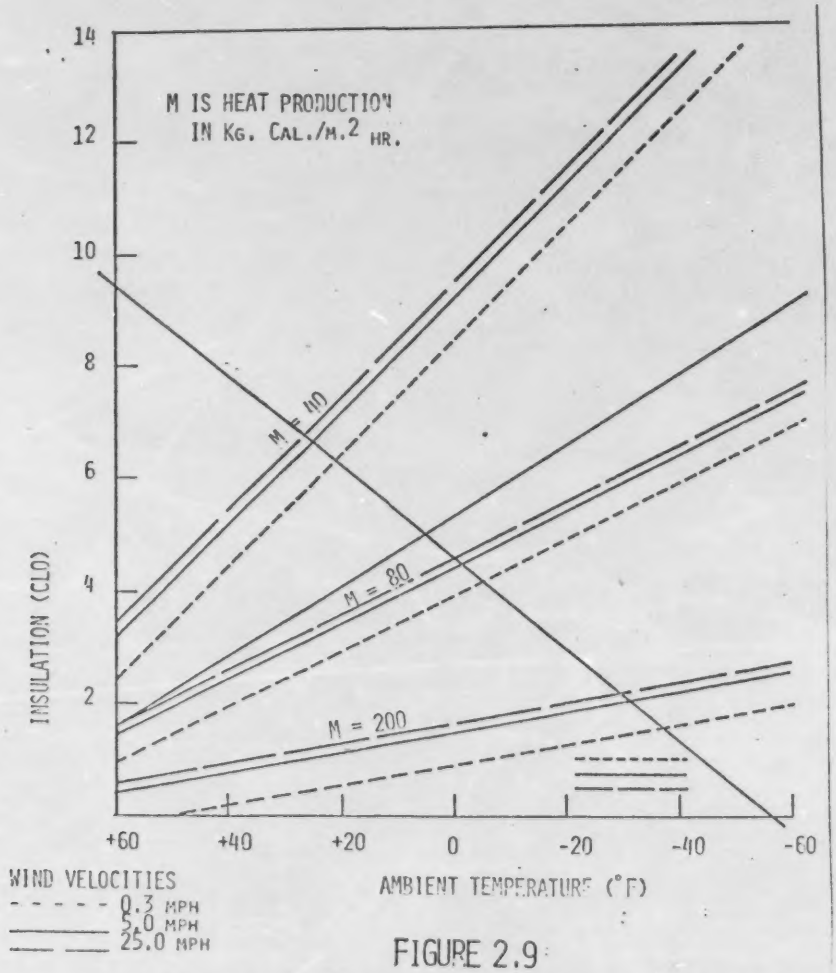


FIGURE 2.9

LECTURE	LABORATORY
You should now know how to plot a comfort zone on a T_{DB}/T_{WB} on a "psychrometric chart" or comfort chart (psychro=humidity; metric= measurement). Psychrometric charts are used extensively by architects, HVAC engineers, and building managers.	Discuss the meaning of the psychrometric chart you have produced.

FIGURE 2.10

OUTDOOR TDB/TWB CHART FOR REPRESENTATIVE TEXAS CITIES

	Higher Summer TDB			Lowest Winter TDB		Daily TDB Range	Highest TWB
	1	2	3	4	5	6	7
WICHITA FALLS	103/73°	101/73°	98/73°	14	18	24	75-77
DALLAS	102/75°	100/75°	97/75°	18	22	20	77-78
CORSICANA	100/75°	98/75°	96/75°	20	25	21	77-79
AUSTIN	100/74°	98/74°	97/74°	24	28	22	77-78
EL PASO	100/64°	98/64°	96/64°	20	24	27	68-69
SAN ANTONIO	99/72°	97/73°	96/73°	25	30	19	76-77
AMARILLO	98/67°	95/67°	93/67°	6	11	26	70-71
HOUSTON	97/77°	95/77°	93/77°	28	33	18	79-80
CORPUS CHRISTI	95/78°	94/78°	92/78°	31	35	19	79-80

ALL VALUES IN °F TDB/TWB EXCEPT WHERE INDICATED

1. COLUMN 1, 2 AND 3 GIVE TDB/TWB FOR 1%, 2-1/2% AND 5% OF SUMMER DAYS. ONLY 1 DAY IN 100 IS COLUMN 1 EXCEEDED; ONLY ON 2-1/2 DAYS IS COLUMN 2 EXCEEDED AND SO ON.

2. COLUMNS 4 AND 5 GIVE TDB FOR 99% AND 97-1/2% OF WINTER DAYS. IN 99% (97-1/2%) OF WINTER DAYS, THESE VALUES ARE EXCEEDED.

3. COLUMN 6 SHOWS THE MEAN DAILY RANGE IN TDB. THUS, EL PASO COMMONLY EXPERIENCES A TDB FLUCTUATION OF 27°F BETWEEN THE HOTTEST HOUR DURING THE DAY AND THE COLDEST HOUR DURING THE NIGHT.

4. COLUMN 7 SHOWS TWB FOR THE 15 DAYS WHEN THE ATMOSPHERE WAS MOST HUMID IN A RECENT 5 YEAR PERIOD. THUS, CORPUS CHRISTI AND HOUSTON EXPERIENCE GREATER HUMIDITY THAN AMARILLO AND EL PASO.

UNIT 3: CONTROLLING BUILDINGS FOR THERMAL COMFORT

Goal Statement:

On completion of lesson 3, the student will be able to explain why thermal controls in homes and workplaces need to be set in accordance to the occupancy and duration of stay, and why activity and clothing are important in achieving heat balance and comfort.

LECTURE	LABORATORY

UNIT 3:

a. Occupancy and Duration

The temperature, humidity, and air-movement inside a building may be controlled either for purposes of human comfort or for some other purpose, such as safety, odor removal, or storage of contents. If controlled for human thermal comfort, it is important to know the rate of occupancy, (that is, how many persons will be inside). It is also important to know the duration of occupancy, (that is, whether persons typically remain in the building for a few minutes at a time, for 1 hour, for 4 hours, or for longer periods). Certain buildings, such as sports arenas and churches, are usually occupied by a large number of persons for a short period of time, perhaps 1-3 hours. Moreover, church services and sports events may take place only once or a few times per week.

Discuss the occupancy of your school building. Was your classroom occupied at 8 a.m. this morning? For how long? What was the number of occupants? What will be the school occupancy at 8 p.m. tonight? 8 p.m. on Saturday night during a social function? 8 p.m. next Sunday night? Is there a difference between the occupancy of the entrance space, the classroom, the offices, and the kitchens.

LECTURE

Different spaces have different thermal thermal conditioning requirements according to both occupancy and duration stay. This means that the enclosed environment can be maintained at different comfort index values for comfort zones, depending on load and occupancy lelves. A classroom which is occupied by 30 persons for 90 minutes will heat up because of body heat production, and must be both cooled and ventilated. An entrance hallway of the same size may have 30 persons pass through it in 90 minutes, but there will be no need to cool or ventilate it to classroom comfort conditions because the duration of occupancy is very short. Persons readily adapt and feel comfortable in a wide range of temperatures if they plan to leave again shortly or are merely passing through.

LABORATORY

Review the table at Figure 3.1. Which spaces or buildings are likely to be occupied continuously by the same person for three or more hours? Does the space then remain empty?

FIGURE 3.1

OCCUPANCY AND DURATION OF STAY IN BUILDING TYPES

SPACE OR BUILDING	OCCUPANCY	DURATION OF STAY PER PERSON
1. ENTRANCE LOBBIES	FEW AT A TIME	SHORT
2. ELEVATORS	ONE OR SEVERAL	SHORT
3. CONVENIENCE STORES	SEVERAL	MINUTES
4. RESTAURANTS	VARIABLE	1/2 - 1 HOUR
5. CLASSROOM	SUBSTANTIAL	3/4 - 1 1/2 HOURS
6. LIBRARIES	SEVERAL OR MANY	VARIABLE
7. CHURCHES	SUBSTANTIAL	1-2 HOURS
8. SPORTS ARENAS	THOUSANDS	2-3 HOURS
9. MOVIE THEATERS	HUNDREDS	2-4 HOURS
10. OFFICES	FEW	8 HOURS
11. MOTEL ROOM	ONE OR TWO	8 HOURS OR MORE
12. HOSPITAL ROOM	ONE OR TWO	24 HOURS OR MORE

LECTURE	LABORATORY
Preferred temperatures are usually measured for 1, 2 or 3 hour periods, either by vote or by preferred thermostat settings. Average values are plotted as "comfort lines" on a graph of T_{DB} vs T_{WB}. (See Figure 3.2)	Do the graphs at Figure 3.2 show any difference between 1-hour comfort and 3-hour comfort for men? For women? Do women prefer a warmer temperature than men for 1 hour? If moist air is dehumidified by removing water or by mixing with dry outside air, is a warmer or cooler T_{DB} preferred? Note that a range of 30°- 70° relative humidity (RH) is commonly accepted, but that RH will rise quickly in a well occupied classroom or other space. Why? Discuss the differences in occupancy and duration of use in your classroom? Are there any other factors which affect your comfort (i.e., air movement type of activities performed, number of occupants, time of day, if the period follows recess or lunch, etc.)

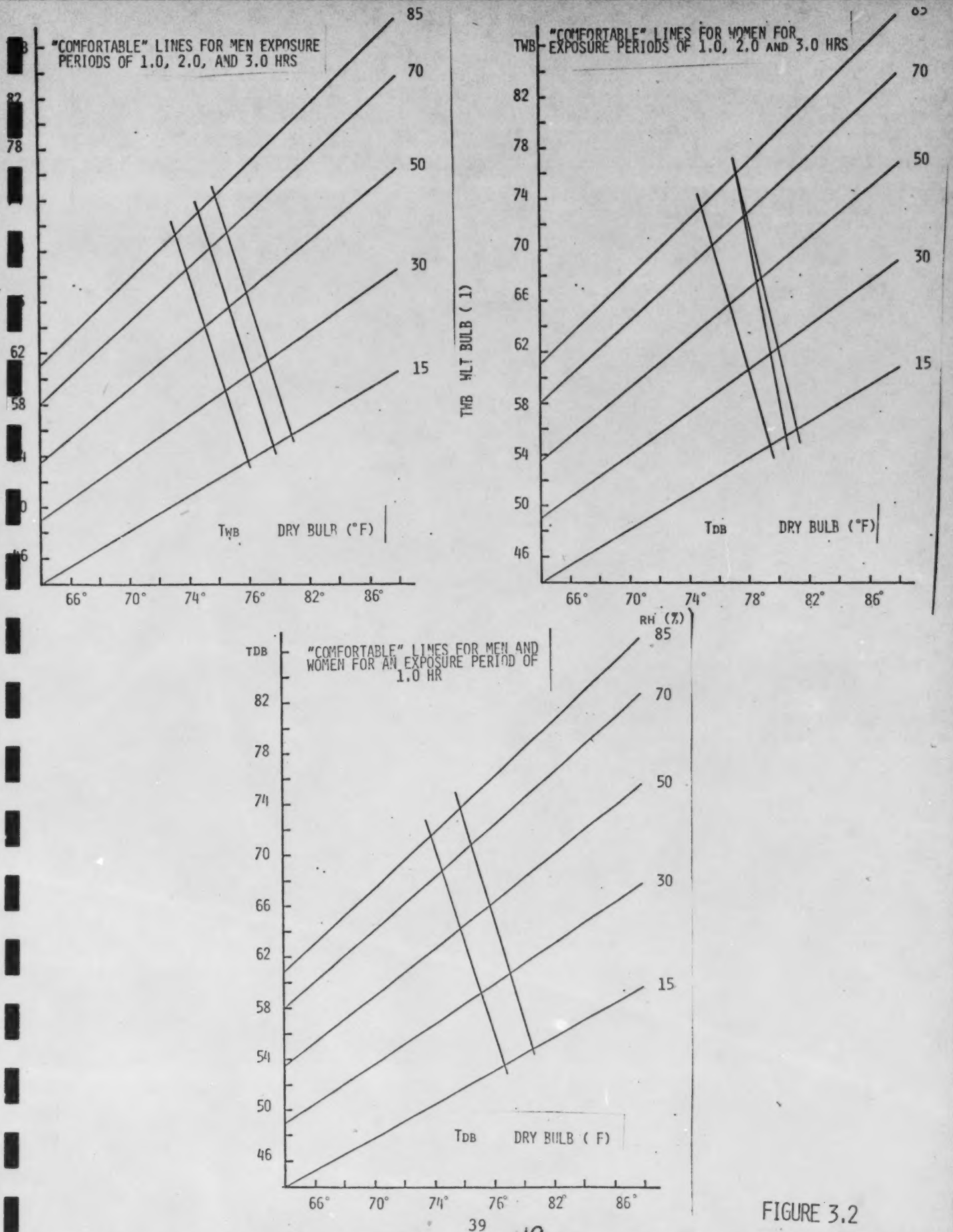

"COMFORTABLE" LINES FOR MEN EXPOSURE PERIODS OF 1.0, 2.0, AND 3.0 HRS
TWB WLT BULB (°F)
TWB DRY BULB (°F)
66° 70° 74° 76° 82° 86°
82 78 62 58 46
85 70 50 30 15
"COMFORTABLE" LINES FOR WOMEN FOR EXPOSURE PERIODS OF 1.0, 2.0 AND 3.0 HRS
TWB
TDB DRY BULB (°F)
66° 70° 74° 78° 82° 86°
82 78 74 70 66 62 58 54 50 46
85 70 50 30 15
"COMFORTABLE" LINES FOR MEN AND WOMEN FOR AN EXPOSURE PERIOD OF 1.0 HR
TDB
RH (%)
TDB DRY BULB (°F)
66° 70° 74° 76° 82° 86°
82 78 74 70 66 62 58 54 50 46
85 70 50 30 15

FIGURE 3.2

LECTURE	LABORATORY

UNIT 3:

b. Activity and clothing

For the human body to remain in continued thermal comfort, the following conditions must apply:

Heat Balance Equation:

BODY HEAT PRODUCTION = BODY HEAT LOSS TO SURROUNDINGS

long term — long term

Body heat production is raised by activity, physical work, and eating. Body heat loss is decreased by raising the temperature, reducing air movement, or increasing the clo insulation value of garments worn. If any or all of these factors come int play, the skin and body temperature (T_{SK}, T_{body} will rise. Thus, the heat balance equation is rearranged as follows:

BODY HEAT PRODUCTION = BODY HEAT LOSS TO SURROUNDINGS

shifts temporarily to the following:

BODY HEAT PRODUCTION - BODY HEAT LOSS TO SURROUNDINGS = BODY HEAT STORAGE

What are the responses of the body to heat storage? Initially, there is an increase in breathing rate, greater blood flow to the skin and a feeling of warmth and perhaps discomfort. If continued, they progress further into sweating, heavy breathing, flushing of blood to the skin, and loss of attention. Option available to restore comfort are:

Take body temperature measurements at rest, after mild activity, and after strenuous activity.

Plot temperature as a function of time, during and after activity.

(a) reduced heat production,
(b) increased convective cooling,
(c) increased evaporative cooling.
(d) reduced thermal insulation.

(a) is assisted by intermittent work, rest pauses, and slower work. (b) (c) and (d) are assisted by reducing the number of garments worn, by moving to a cooler area, or by fanning the air. This is the reason people lose attention and move into a draft of air, toward a window, or into a cool, shaded area in early heat stress. Dehydration, heat fatigue, loss of temperature, and heat death are the result of exposure to prolonged, intense heat without compensation or treatment. This is why a supply of clear, chilled drinking water or other beverage is helpful, not only for drinking but for wetting the skin. This is why summer clothing is usually light colored, has few layers, uses thin fabrics, and exposes more skin for evaporation than does winter clothing. It is also the reason the amount of clothing is adjusted during a summer day from several layers, long-sleeved garments, and closed or buttoned shirts/blouses in cool hours, to single layers, skimpy garments, and partially unbottoned shirts/blouses in the hot hours.

The most restful activities associated with least heat-production are sleeping, lying, reclining, and sitting. Heat production is more than doubled in light work, quadrupled in moderate activity, and increased 10X - 20X by athletes and persons accustomed to hard physical labor. Body size and sex are also important. Tall and heavy persons produce more heat than short, light ones, even when performing the same task or activity. The table in Figure 3.3 gives representative heat-production rates for men and women in BTU/hr for men of typical North American stature and build. Description of units and adjustments for sex and different body size are given in footnotes. One MET is the heat production of an average male adult during complete rest.

FIGURE 3.3
TABLE OF HEAT PRODUCTION RATES

	Typical values for BTU/hr
Asleep	
Sleeping, men over 40	260
Sleeping, men aged 30-40	280
Sleeping, men aged 20-30	280
Resting	
Lying moderately relaxed	320
Lying awake--after meals	340
Sitting at rest	400
Very light activity--seated	
Writing	430
Typing	550
Polishing	570
Very light activity--standing	
Relaxed	440
Typing	460
Polishing	480
Light activity--seated	
Playing musical instruments	690
Repairing boots and shoes	720
At lecture	730
Light activity--standing	
Washing clothes	610
Ironing	890
Scrubbing	1040
Light activity--moving	
Slow movement about room	600
Vehicle repair	820
Washing	1000
Moderate activity--sitting	
Rowing for pleasure	1190
Cycling at 8-11 mph	1360
Cycling rapidly	1640

FIGURE 3.3 CONTINUED:

	Typical values for BTU/hr
Moderate activity--standing	
Gardening	1380
Chopping wood slowly	1480
Shoveling sand slowly	1620
Moderate activity--moving	
Golf	1290
Table tennis	1380
Tennis	1500
Heavy activity--lying	
Leg exercises, average	1790
Swimming breast stroke at 1.6 mph	1950
Swimming backstroke at 1.0 mph	1980
Heavy activity--sitting	
Cycling rapidly--own pace	1980
Cycling at 10 mph--heavy bicycle	2120
Cycling in race 100 mi in 4 hr., 22 min.	2340
Heavy activity--standing	
Chopping wood rapidly	1790
Shoveling sand rapidly	1830
Sawing wood by hand	1900
Heavy activity--moving	
Skating at 9 mph	1860
Skiing at 8 mph on level	2140
Climbing stairs at 116 steps per minute	2340
Very heavy activity--sitting	
Cycling at 13.2 mph	2380
Galloping on horseback	2720
Sculling 97 strokes/min.	3000

FIGURE 3.3 CONTINUED:

	Typical values for BTU/hr
Very heavy activity--moving	
Fencing	2500
Playing basketball	2720
Climbing stairs	2860
Extreme activity	
Wrestling	3100
Marching at double time	3160
Endurance marching	3520

Note:

BTU/hr is the rate of heat production per hour. These measurements are given for a person 69 inches tall and 167 pounds, in absolute units.

LECTURE

The effects of exercise on heat production continue for variable periods of time, lasting into the rest period for at least 1 hour in many instances.

To achieve heat balance during work on adjustment must be made to increase heat loss. This is achieved either by wearing less clothes or by reducing the T_{DB} and T_{WB} below resting comfort levels. To achieve heat balance at rest, air adjustment must be made to decrease heat loss. This is achieved either by wearing more clothing or by increasing T_{DB} and T_{WB} to comfort levels.

How much adjustment is needed to achieve heat balance? This depends on the level of body heat production, and or the environmental conditions. At 75°F, 50% R.H. (relative humidity), and 30 f.p.m. air movement, the table at Figure 3.4. applies:

LABORATORY

Verify from Figures 3.3. and 3.4 that a person climbing stairs produces 10X (ten times) as much heat for a few minutes as he does when sleeping or lying relaxed. Also that a large female or average male produces 25%-30% more heat than a smaller person of the same size performing the same task.

FIGURE 3.4
HEAT LOSS

Typical Activity	Evaporative Heat Loss	Clo for Heat Balance
SLEEPING	53 BTU/HR.	0.6 LIGHT WINTER CLOTHING
SCRUBBING	226 BTU/HR.	0.14 T-SHIRT & BRIEFS, BRA & SHORTS
CLIMBING STAIRS	644 BTU/HR.	0.05 BRIEFS ONLY

LECTURE	LABORATORY

It shows that one twelfth of the clo value at rest is needed during heavy work such as stair climbing. Discuss the implications of this for dress during work. Would an alternative be to raise the air movement to 100 f.p.m.? Why? If T_{DB} and T_{WB} are reduced excessively, as for example in over-cooled rooms or in winter, the body responses are:

(a) blanched skin and "goose-bumps"
(b) shivering,
(c) increased body heat production,

followed by:

(d) increased need for food,
(e) T(skin) reduced below comfort level,
(f) T(body) reductions and body chills,
(g) colds and respiratory infections including pneumonia and influenza.

If prolonged, excess deaths occur, even among healthy, outdoor workers and young adults. In freezing outdoor temperatures and winter windstorms, frostbite and cold injuries occur unless heavy protective clothing (clo values: 2-4 units) is worn. In the Texas Panhandle, temperatures below zero° and winter windstorms frequently cause severe body chilling during December and January due to cooling and wind chill factor.

LECTURE	LABORATORY

UNIT 3:

c. Workplaces vs. homes

Workplaces are usually air-conditioned for shift work and the comfort of healthy workers of between the ages of 16-65 years. Locations of heavy and light occupations are usually segregated and individually air-conditioned. Eight hours is a common limit to the working day, and occupancy changes thereafter. In any particular working area, the adjustment of temperature conditioning to activity level, clothing, and heat

Set up thermographs for 24 hours in a typical workplace, such as;

(a) a large office
(b) a machine shop
(c) a garage or workshop
(d) a power plant
(e) a boiler room
(f) a warehouse or storage area.

Observe and record the type of air conditioning, thermostat setting, clothing worn, and ventilation used. Compare the differences.

LECTURE	LABORATORY
balance is accomplished to group satisfaction because group members have similar comfort needs. Special requirements can be met by zoning workplaces for special cooling, ventilation, screening, or warming.	Set up thermographs for 24 hours in typical homes of different construction, with and without air conditioning.
By contrast, houses are the 24-hour, 7-day residence of unselected population sub-groups, ranging from babies to retired persons, active to inactive children and adults, and both healthy and sick persons. Each subgroup, perhaps represented by one individual in the family, has a thermal comfort zone related to his heat balance. In bedroom areas where 8-hour sleeping periods of very low heat production is the usual activity, the comfort zone is very different from that in a garage, workshop, home laundry, kitchen, or play area. Seasonal variations exert maximum effects on the temperature and humidity of small houses and mobile homes; in inland areas, with smaller variations, in larger, single family houses in coastal areas, where humidity and nature ventilation are uniformly higher, but temperature extremes are rare. In multifamily homes, and especially larger apartment blocks, there is greater use of control temperature conditioning and sometimes humidity control, with correspondingly more uniformity in indoor climate control. Older, non-conditioned apartment houses are, by contrast, less capable than any other group of being comfort conditioned.	Observe and record the number of residents at home and the type of air conditioning or ventilation in use, if any.
Night/day fluctuations of temperature are best recorded by 24-hour or 7-day thermographs. Use of several thermographs in different parts of the same work-place or house allows the cycling effect of cool/night and warm/day conditions to be seen. The effects are most marked in open work spaces. Seasonal changes are also observed to be very marked in such locations. Very substantial temperature cycles are common in non-conditioned or poorly insulated homes. This fluctuation also presents special problems in poorly constructed housing and in areas of high utility	Compare the thermograph highs and lows in the different locations and relate them to the activities of the occupants.

LECTURE	LABORATORY

rates because of added expenses and difficulty in achieving temperature control where doors and windows allow air seeping through or air infiltration.

Two problems remain. First, the temperature-controlling mechanisms of the body are poorly developed in young children and sometimes impaired in older persons. Neither group is able to operate thermostats or windows for their personal comfort. Body chilling and overheating require attention and assistance to prevent adverse health effects. Second, person-to-person difference in size, body build, activity level, attention span and mobility make it difficult to achieve satisfactory home air conditioning where several children are in the family. Not only are thermal comfort zones different for various sizes, ages, and both sexes, but many children add and discard clothing in the process of play and frequently move from indoors to outdoors and vice versa. In such conditions, neither body thermal balance nor room temperature control are feasible. This is undoubtedly a contributing factor to childhood respiratory diseases and the incidence of short term fevers.

The summer months in Texas see an increase in deaths related to the extreme heat. In what age group would you suppose most would occur? What problems and illnesses would be suceptible to heat? What steps, if any, could be used to prevent collaspse and death.

LECTURE	LABORATORY

UNIT 3:

d. Energy-Saving Options

Active controls, such as thermostats are devices which activate heating, ventilating, or cooling systems at constant power and then cut off when the set temperature point has been achieved.

Passive controls such as switches are those operated at the option of users. If left in the minimum load or "off" position until needed, and if turned "on" as soon as comfort levels are inadequate, such controls are energy-saving. Time controls, such as those which activate heating lamps and other devices for a limited period, are also energy-saving devices used in comfort conditioning. With the rise in utility and fuel costs in Texas in the period 1972-78 (electricity: 2.51¢ to 6.00¢ per kilowatt hour; natural gas: 25¢ to $2.35 per thousand cubic feet in typical areas) the available options for energy-saving include:

(a) Retain comfort control settings and pay the increased prices according to variations in climate.

(b) Adjust comfort control settings to operate at higher summer temperatures and lower winter temperature within the broad-range of the comfort zone.

(c) Install time controls or passive controls in such a way that HVAC equipment will run only when buildings are occupied.

(d) Convert from high cost/low efficiency equipment to low cost/high efficiency HVAC equipment for ventilation, cooling, and heating.

(e) Eliminate use of air conditioning for all months in which outside temperatures are within the comfort zone.

(f) Adjust air conditioning and heating to compensate for internal heat gains from the number of people, lighting, cooking, and related factors.

(g) Increase air movement for evaporation and convective cooling by use of ceiling fans, pedestal fans, and natural ventilation.

LECTURE	LABORATORY
(h) Adjust clothing insulation daily to conserve heat when cool and increase heat loss when hot.	
(i) Introduce single-room, zone, or spot air conditioning or ventilation in place of total air conditioning.	
(j) Maximize the benefit of natural seasonal acclimatization by adopting seasonal clothing styles/types and by repeated daily open-air exposure.	
(k) Utilize existing architectural and construction features by selecting most appropriate rooms and locations for specialized activities, based on their measured temperature differences.	
(l) Develop future architectural and construction features which will maximize the utility of natural ventilation, shade and evaporative cooling in summer, and solar heating in winter, and reduce unwanted cold-night/hot-day cycling.	
	Discuss the feasibility and importance of items (a) to (l). Discuss tradeoffs which can be used to accomplish energy conservation.

SUMMARY

Many options exist for improving thermal comfort passively and by changed behaviorial patterns. Human comfort is affected by many variables, both energy-using and energy-conserving. Tradeoffs exist between the acceptance of hour-to-hour, day-to-day, and season-to-season changes in temperature within the comfort zone, and the use of energy to control temperature to narrow these limits. Energy conservation and cost savings in buildings are achieved by greater attention to variable levels of tradeoffs, with natural climate and human adaptability as important variable components.

MODULE #9
HUMAN COMFORT AND ENERGY CONSERVATION

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BODY TEMPERATURE CHART

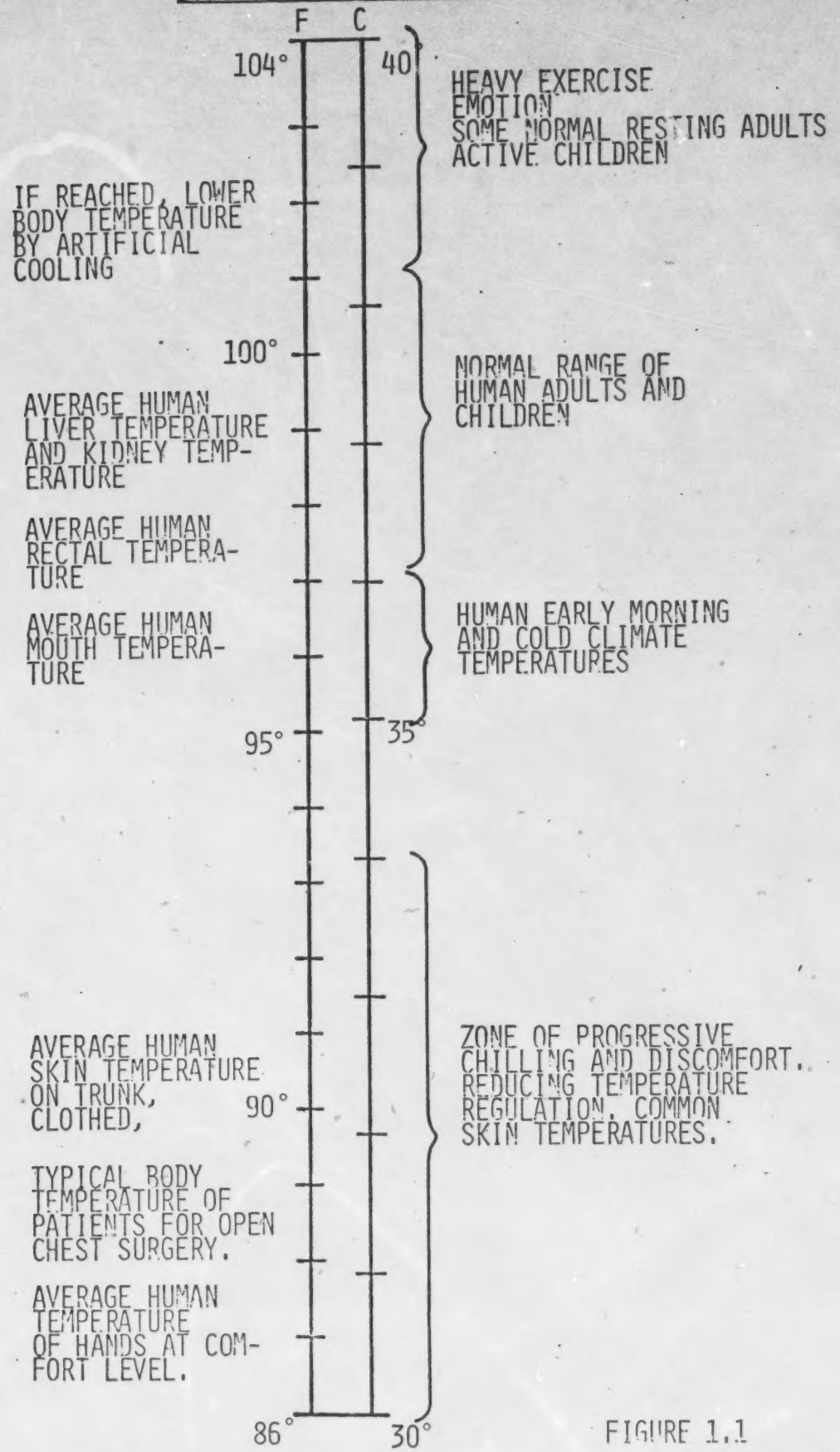


FIGURE 1.1

COMPENSATORY RESPONSES

	THERMAL SURROUNDINGS	HEAT PRODUCTION CHANGE
1	COLD AIR WINTER SEASON COLD CLIMATES	INCREASED PHYSICAL ACTIVITY INCREASED FOOD INTAKE DECREASED FLUID INTAKE AND SWEATING
2	HOT AIR SUMMER SEASON HOT CLIMATE	DECREASED PHYSICAL ACTIVITY DECREASED FOOD INTAKE INCREASED FLUID INTAKE AND SWEATING

COMPENSATION IS OVER A PERIOD OF TIME AND IS PARTLY VOLUNTARY.

FIGURE 1.2

ADJUSTMENTS TO SKIN HEAT LOSS

	THERMAL SURROUNDINGS	SKIN-BLOOD FLOW CHARGE
1	COLD AIR LOW THERMOSTAT SETPOINT LOW SURFACE TEMPERATURES	BLANCHES SKIN, REDUCED BLOOD FLOW, LIMITED SWEATING, SHIVERING; INCREASED HEAT PRODUCTION
2	HOT AIR HIGH THERMOSTAT SETPOINT HIGH SURFACE TEMPERATURES	PINK SKIN, INCREASED BLOOD FLOW SWEAT RATE RAISES; INCREASED HEAT LOSS; AREA OF MOIST SKIN INCREASED

ADJUSTMENTS ARE RAPID AND CONTROLLED BY NERVOUS REFLEX.

FIGURE 1.3

TEMPERATURE-TIME SUPVIVAL CHART

THE MAN-MADE ENVIRONMENT-TEMPERATURES FOR HUMAN SURVIVAL IN AIR

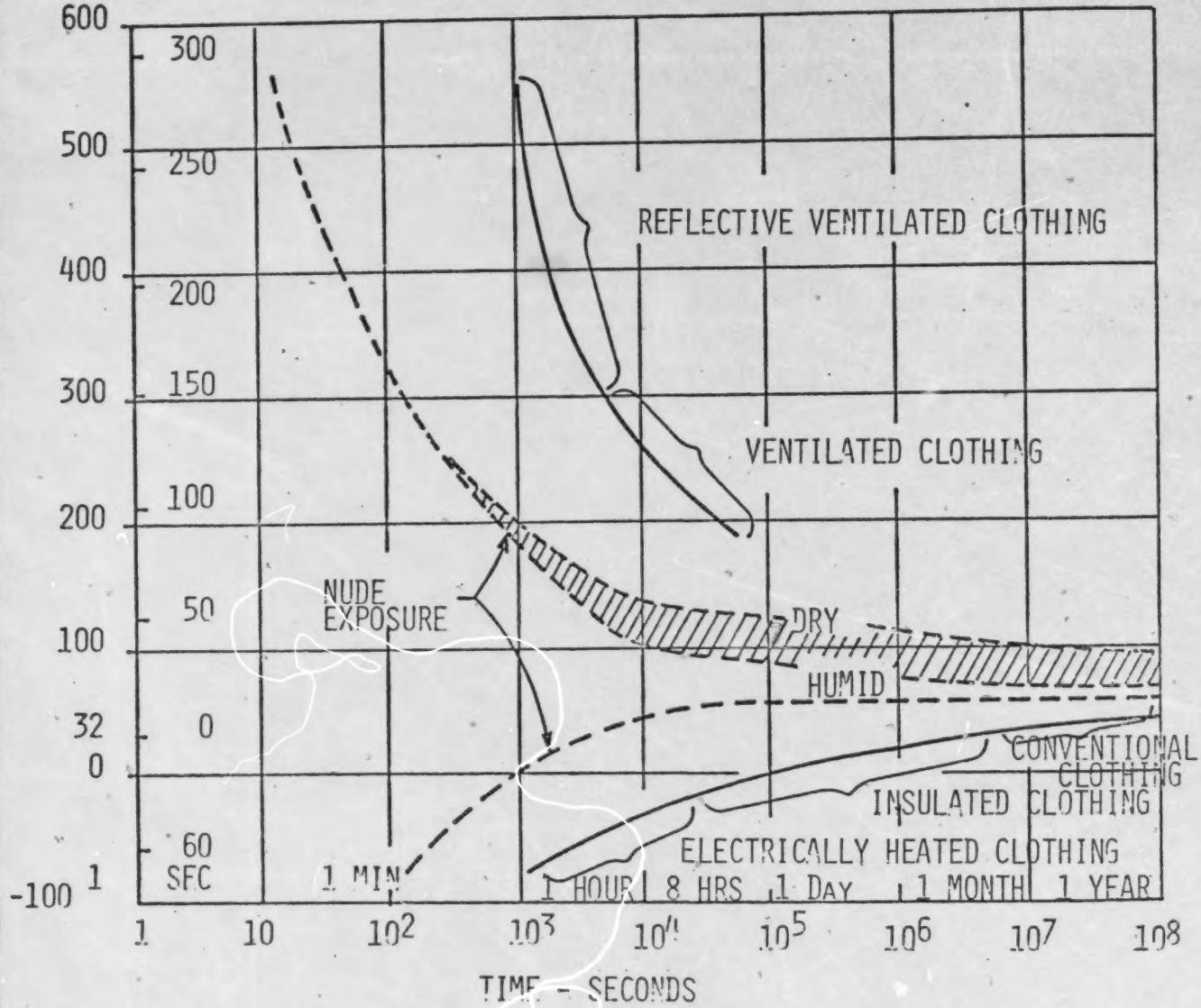


FIGURE 1.4

COMFORT SCORE GUIDE

THE DESCRIPTIONS BELOW REPRESENT THE GRADUATING SCALE FOR INDICATING DEGREES OF COMFORT.

1. COLD
2. COOL
3. SLIGHTLY COOL
4. COMFORTABLE
5. SLIGHTY WARM
6. WARM
7. HOT

FIGURE 1.5

CLOTHING ENSEMBLE CLO VALUES

	An average of 12 sedentary indoor clothing ensembles.	Light, summer, sub topical.	Heavy, winter, Northern USA.
MEN	0.76	0.38	1.18
WOMEN	0.74	0.27	1.20

(All values in clo units)

FIGURE 1.7

INDIVIDUAL GARMENTS: INSULATION IN CLO UNITS

INSULATION VALUE *	MEN	WOMEN
0.01	-	PANTIHOSE
0.02	SANDALS	SANDALS
0.03	COOL SOCKS	COOL SOCKS
0.04	SHOES	GIRDLE
0.05	BRIEFS	BRAS & PANTIES
0.06	UNDERSHIRT	MINI SKIRT
0.09	T-SHIRT	SUMMER SHIRT
0.14	COOL L.S. KNIT SHIRT	HALF SLIP
0.19	WOVEN S.S. SHIRT	SUMMER BLOUSE
0.26	SUMMER TROUSERS	SUMMER PANTS
0.29	WOVEN L.S. SHIRT	P.S. BLOUSE
0.32	WARM TROUSERS	-
0.37	L.S. WINTER SWEATER	L.S. WINTER SWEATER
0.49	WARM JACKET	WARM DRESS
0.63	-	

* CLO VALUES ARE ADDED FOR EACH GARMENT WORN IN AN ENSEMBLE TO OBTAIN OVERALL CLOTHING INSULATION.

CLOTHING MATERIAL CHARACTERISTICS

	Cotton	Linen	Wool	Silk	Acetate	Triacetate	Acrylic Modacrylic	Nylon	Olefin	Polyester	Rayon
Absorbency	+	+	+	+	-	-		-		-	+
Appearance & Hand				+	+	+	+				+
Colorfastness	+	+	+	+	-		+	+		+	+
Dimensional stability		+		+	+	+	+/-	+		+	-
Drapability				+	+	+					+
Durability		+									
Dyeability	+		+	+					-		+
Elasticity								+			
Laundrability	+										
Pressed-in crease retention	-	-	+	-	-		+			+	
Resiliency			+				+	+		+	-

FIGURE 1.8

	COTTON	LINEN	WOOL	SILK	ACETATE	TRIACETATE	ACRYLIC	MODACRYLIC	NYLON	OLEFIN	POLYESTER	RAYON
RESISTANCE:												
ABRASION		-		-	-	-	-	+	+	+		-
AGEING				-					+			
CHEMICALS			-				+		+			
FRICTION			-									
HEAT	+	+		-		+						
MILDEW	-	-			+		+	+			+	-
MOTHS	+	+	-		+		+	+	+		+	
PERSPIRATION	+	+	-	-				+	+		+	
PILLING			-				-	-	+			
STAINS									+		-	
SUNLIGHT	-	-	+	-			+	-	+		+	
WEATHER									+		-	
WRINKLING	-	-	+	+	-	+	+	-	+		+	-
SOFTNESS	+						+					-
STRENGTH												
WET	+			-	-	-	-	+			+	
DRY	+			+	-	-	-	+			+	
WARMTH			+				+				+	
WASH & WEAR												
QUALITY	-		-		-	+	+				+	-
WATER REPELLENCY			-									

SOURCE: "FIBERS AND FABRICS," BY J. M. BLANDFORD AND L. M. GUREL, CONSUMER GUIDE FROM THE NATIONAL BUREAU OF STANDARDS: GAITHERSBURG, MD 20760, 1970.

+ =GOOD TO EXCELLENT
- =FAIR TO POOR

FIGURE 1.8 (continued)

FIGURE 1.9

APPROXIMATE CALORIC VALUES OF SOME COMMON FOODS

CALORIC VALUES ARE GIVEN IN NUMBERS THAT ARE MULTIPLES OF FIVE TO SIMPLIFY THE ESTIMATING OF TOTAL CALORIES.

FOOD	SIZE OF SERVING	APPROXIMATE CALORIES
FOODS CLASSED AS LARGELY CARBOHYDRATES:		
APPLES, RAW	1 MEDIUM	75
APPLE PIE	1/6 MEDIUM PIE	400
APPLE SAUCE	1/2 CUP	95
APRICOTS, CANNED	3-4 AND 2 T. JUICE	75
APRICOTS, FRESH	2-3	55
APRICOTS, DRIED	4-6 HALVES	100
ASPARAGUS, RAW	8-12 STALKS 5"	25
ASPARAGUS, CREAMED	1/4 CUP	100
BANANAS, FRESH	1 MEDIUM	100
BEANS, STRING, FRESH	1 CUP	25
BEETS, SLICED, FRESH	1 CUP	65
BISCUITS, BAKING POWDER	1 MEDIUM	100
BLACKBERRIES, FRESH	1/2 CUP	40
BLANC MANGE, CHOCOLATE	1/2 CUP	220
BLANC MANGE, PLAIN	1/2 CUP	150
BREAD, WHOLE WHEAT	1 SLICE, 1/2"	55
BREAD, WHITE ENRICHED	1 SLICE, 1/2"	60
BREAD, WHITE, RAISIN	1 SLICE, 1/2"	65
CABBAGE, RAW	1 1/4 CUP	30
CAKE, ANGEL	PIECE 3" CIRCUMFERENCE	140
CAKE, CUP, PLAIN	1 MEDIUM	200
CAKE, PLAIN	PIECE 2" X 1"	110
CAKE, SPONGE, HOT WATER	PIECE 3" CIRCUMFERENCE	155
CANTALOUPE	1/2 MEDIUM	45
CARBONATED BEVERAGES	6 OUNCES	80
CARROTS, RAW	2, 4" LONG	40
CARROTS, STEAMED, CUBED	1/2 CUP	20

CAULIFLOWER, STEAMED	1 CUP	30
CAULIFLOWER, RAW	1 CUP	25
CELERY	3/4 CUP OR 4 STALKS	20
CHERRIES, SOUR, FRESH, STONED	1 CUP	65
CHERRIES, SWEET, FRESH, STONED	1 CUP	65
CHOCOLATE, BITTER	1 SQUARE	140
CHOCOLATE CREAM MINT	1	50
CHOCOLATE FUDGE	PIECE 1 1/2" x 1" x 3/4"	100
COCOA, POWDERED	1 T.	20
COCONUT, PREPARED	1/3 CUP	115
CORN, CANNED	1/3 CUP	60
CORN, GREEN	1 MEDIUM EAR	85
CORN SYRUP	1/2 CUP	470
CORNFLAKES	1 CUP	50
CORNMEAL, COOKED	2/3 CUP	80
CORNMEAL, RAW	1/4 CUP	130
CORNSTARCH	1 T.	35
CRACKERS, GRAHAM	1	35
CRACKERS, SODA	1	30
CRANBERRY JELLY	2 T.	100
CREAM PIES WITH MERINGUE	1/6 MEDIUM PIE	300
CUCUMBER, FRESH	1/2 CUP OR 1 SMALL	15
DATES, UNSTONED	3-4	85
DOUGHNUTS	1	170
FIGS, DRIED	2 LARGE	100
FLOUR, WHEAT, WHITE, ENRICHED	1 CUP	405
FLOUR, WHOLE WHEAT	1 CUP	400
FRUIT COCKTAIL	3/8 CUP	100
GRAPEFRUIT	1/2 LARGE	100
GRAPENUTS	1/3 CUP	100
GRAPES, CONCORD, DELAWARE	SMALL BUNCH	80
GRAPES, MALAGA, TOKAY	SMALL BUNCH	75
GRIDDLE CAKES	1 CAKE 4" DIAMETER	80
HOMINY GRITS, COOKED	1 CUP	25
HONEY, STRAINED	1 T.	15
LEMON JUICE	1/2 CUP	10
LEMONS	1 MEDIUM	25
LETTUCE	1/4 LARGE HEAD	20

FIGURE 1.9 (continued)

MACARONI, COOKED	1/2 CUP	230
MAPLE SYRUP	1 T.	50
MINCE PIE	1/6 MEDIUM PIE	455
MUFFINS, PLAIN	1 MEDIUM	115
OATS, ROLLED, COOKED	2/3 CUP	100
ONIONS, RAW	1 SMALL OR 3 T.	10
ORANGE JUICE	1/2 CUP	55
ORANGES	1 MEDIUM	50
PARSNIPS, COOKED	1 MEDIUM OR 1 CUP	95
PEACHES, CANNED	1 HALVES, 3 T. JUICE	85
PEACHES, FRESH	1 MEDIUM	50
PEACHES, DRIED	4 MEDIUM HALVES	145
PEARS, CANNED	2 HALVES, 2 T. JUICE	80
PEARS, FRESH	1 MEDIUM	70
PEAS, CANNED	1/2 CUP	55
PEAS, DRIED, RAW	2 T.	85
PEAS, GREEN, SHELLED	3/4 CUP	75
PINEAPPLE, CANNED	1 SLICE, 3 T. JUICE OR 1 1/2 CUPS SHREDDED	90
PINEAPPLE, FRESH	1 CUP	74
POTATOES, SWEET, BAKED	1/2 MEDIUM	100
POTATOES, WHITE, RAW	1 MEDIUM	100
POTATOES, WHITE, CREAMED	1/2 CUP	150
PRUNES, DRIED	4 MEDIUM	75
PRUNES, STEWED	3 MEDIUM AND 2 T. JUICE	100
RAISINS, DRIED SEEDED	3/4 CUP	320
RASPBERRIES, FRESH	3/4 CUP	75
RHUBARB, FRESH	1 CUP	20
RICE, STEAMED	1 CUP	200
RICE PUDDING, CREAMY	1/2 CUP	110
ROLLS, YEAST	1 MEDIUM	120
SALAD, CHICKEN	1/2 CUP	235
SALAD, TOMATO, LETTUCE	1 SERVING	100
SAUCE, WHITE MEDIUM	1/4 CUP	110
SPINACH, COOKED	1/2 CUP	25
SQUASH, HUBBARD, COOKED	1/2 CUP	50
STRAWBERRIES, FRESH	3/4 CUP	40
SUGAR, BROWN	1 T.	50
SUGAR, GRANULATED	1 T.	50

FIGURE 1.9 (continued)

SUGAR, POWDERED	1 T.	30
SUNDAE, VANILLA ICE CREAM WITH CHOCOLATE SAUCE	1/2 CUP	220
TAPIOCA, CREAM	1/2 CUP	190
TOMATO JUICE	1/2 CUP	25
TOMATOES, CANNED	1/2 CUP	25
TOMATOES, FRESH	1 MEDIUM	30
TURNIP GREENS, COOKED	1/2 CUP	20
TURNIPS, COOKED	1/2 CUP	20
WAFFLES	1, 6" DIAMETER	215
WATERMELON	PIECE 2 1/2" x 2" x 3"	85
WHEAT, SHREDDED	1 LARGE BISCUIT	100
YEAST, COMPRESSED	1 CAKE	25
FOODS CLASSED AS LARGELY PROTEIN:		
ALMONDS, CHOCOLATE	5	105
ALMONDS, SALTED	10-12	95
BEANS, BAKED	1/2 CUP	100
BEANS, LIMA, COOKED	1/3 CUP	100
BEANS, NAVY, COOKED	1/2 CUP	105
BEEF, HAMBURG STEAK, BROILED	CAKE, 2 1/3" DIAMETER, 1/2" THICK	120
BEEF, ROUND, BROILED	PIECE 2 1/2" x 3" x 1/2"	125
BEEF, SIRLOIN STEAK, LEAN, BROILED	PIECE 4" x 3" x 3/4"	350
BUTTERMILK	1 CUP	85
CHEESE, AMERICAN	1" CUBE	115
CHEESE, COTTAGE	1/3 CUP	75
CHICKEN, LEAN MEAT, COOKED	3 SLICES 3 1/2" x 2 1/2" x 1/4"	115
CHOCOLATE BEVERAGE MADE WITH MILK	3/4 CUP	210
EGGS, SCRAMBLED	1/2 CUP	180
EGGS, WHOLE	1	75
FISH, LEAN, BROILED	PIECE 4" x 2 1/4" x 2/3"	125
GELATIN, GRANULATED	1 T.	35
HAM, BAKED	PIECE 4" x 2 1/2" x 3/4"	280
HAM, BOILED	1 OZ.	85
ICE CREAM, VANILLA	1/3 CUP	150
JELLO	1/3 CUP	75
JUNKET, PLAIN	1/2 CUP	115

FIGURE 1.9 (continued)

LAMB CHOP, BROILED	1	250
LAMB ROAST	SLICE 3 1/2" x 4 1/2" x 1/8"	200
LIVER, RAW	PIECE 4" x 3" x 5/8"	130
MILK, SKIMMED	1 CUP	85
MILK, WHOLE	1 CUP	165
OYSTERS, RAW	1/3 CUP OR 3 1/2 LARGE	70
PORK CHOP, BROILED	1 MEDIUM	250
SALMON, CANNED	1/2 CUP	205
SODA WATER WITH VANILLA ICE CREAM	2/3 GLASS	200
SOUP, CREAM OF PEA	1/2 CUP	135
SOUP, CREAM OF TOMATO	1/2 CUP	125
WALNUTS, ENGLISH	10 MEATS OR 1 1/2 T. CHOPPED	100
FOODS CLASSED AS LARGELY FAT:		
BACON, COOKED	2 SLICES	100
BUTTER	1 T.	100
COD LIVER OIL	1 T.	100
COTTONSEED OIL	1 T.	125
CREAM, 40%	1/2 CUP	440
CREAM, 18%	1/2 CUP	245
FRENCH SALAD DRESSING	1/2 CUP	470
LARD	1 T.	125
MAYONNAISE DRESSING	1 T.	90
OLEOMARGARINE, FORTIFIED	1 T.	110
OLIVES, GREEN, UNSTONED	3-4	50
OLIVE OIL	1 T.	135
PEANUT BUTTER	1 T.	90
PEANUTS, SHELLED, ROASTED	9-10	50
RUSSIAN SALAD DRESSING	1 T.	100

FIGURE 2.1

MAXIMUM AND MINIMUM TEMPERATURES

Mean Temperature*		Max. F	Min. F	Range F
TSK	(comfort)	95°	91°	4°
TDB	(comfort)	93°	72°	19°
TSK	(outdoors)	100°	75°	25°
TDB	(outdoors-Texas)	98°	20°	78°
TDB	(outdoors-Continental USA)	105	-3	108
T (surf)	(outdoors-** Texas)	139°	6°	133°
T (surf)	(outdoors-** Continental USA)	168°	NA	NA

*Individual reactions to temperature may vary substantially. The mean TSK is usually the average skin temperature for feet, lower and upper leg, trunk, arms, hands and head. However, the feet and leg temperatures and usually much more variable than the trunk and head TSK. Outdoor TDB are average monthly air temperatures for July and January (max.°F and min.°F, respectively). Mean T (surf) outdoors is the mean of shade and exposed ground temperatures and sky temperature and surface temperature of nearby objects.

** Estimated 1-hour averages on light surfaces. Computer models for dark surfaces predict occasional values as high as 198°F for one hour.

FIGURE 2.2

EXPERIMENT

TIME	TDB	CLOSED CONTAINER	TWB	OPEN CONTAINER
BEFORE STARTING FAN	SAME AS AIR TEMPERATURE	HOT (T HOT)	SAME AS AIR TEMPERATURE	HOT (T HOT)
AFTER 5 MINUTES	AS ABOVE	STILL HOT	DROPS	SOMEWHAT COOLER
AFTER 30 MINUTES	AS ABOVE	SOMEWHAT COOLER	NO FURTHER CHANGE*	COOLER THAN CLOSED CONTAINER
AFTER 60 MINUTES	AS ABOVE		NO FURTHER CHANGE*	MUCH COOLER

*IF THE WICK IS ALLOWED TO GO DRY, NOTE THAT TWB WILL RISE UNTIL TWB = TDB. CONFIRM THIS. KEEP THE WICK MOIST FOR ACCURATE TWB READINGS.

TEMPERATURE - HUMIDITY - COMFORT RELATIONSHIPS

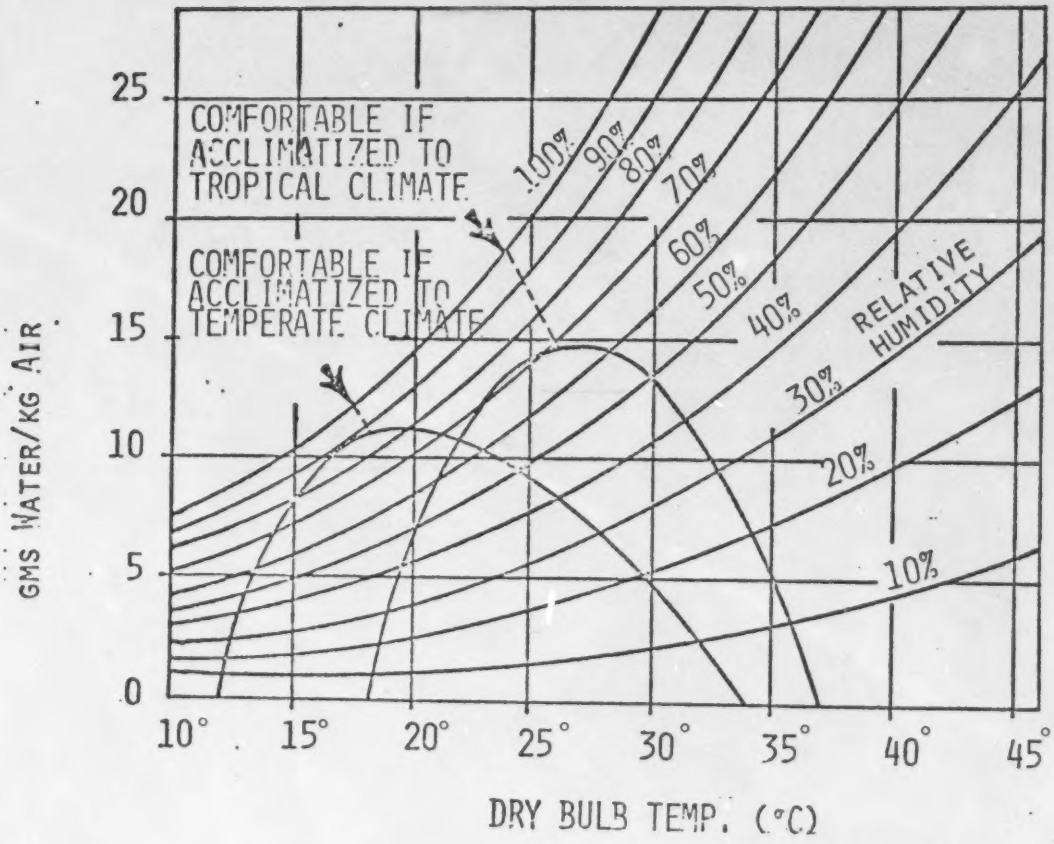
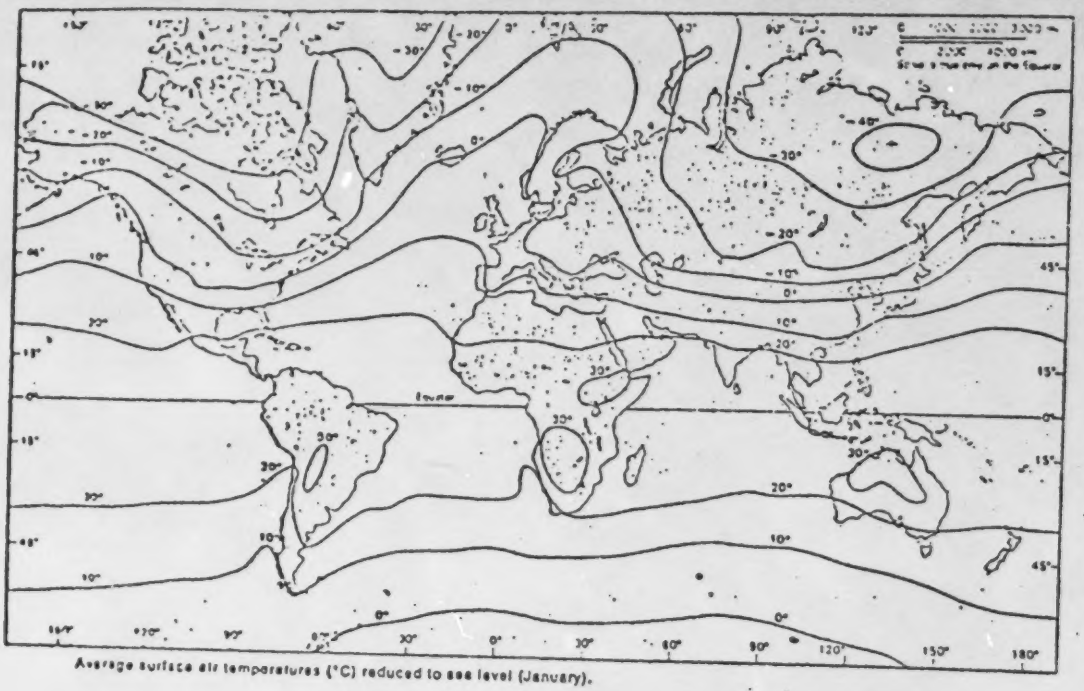
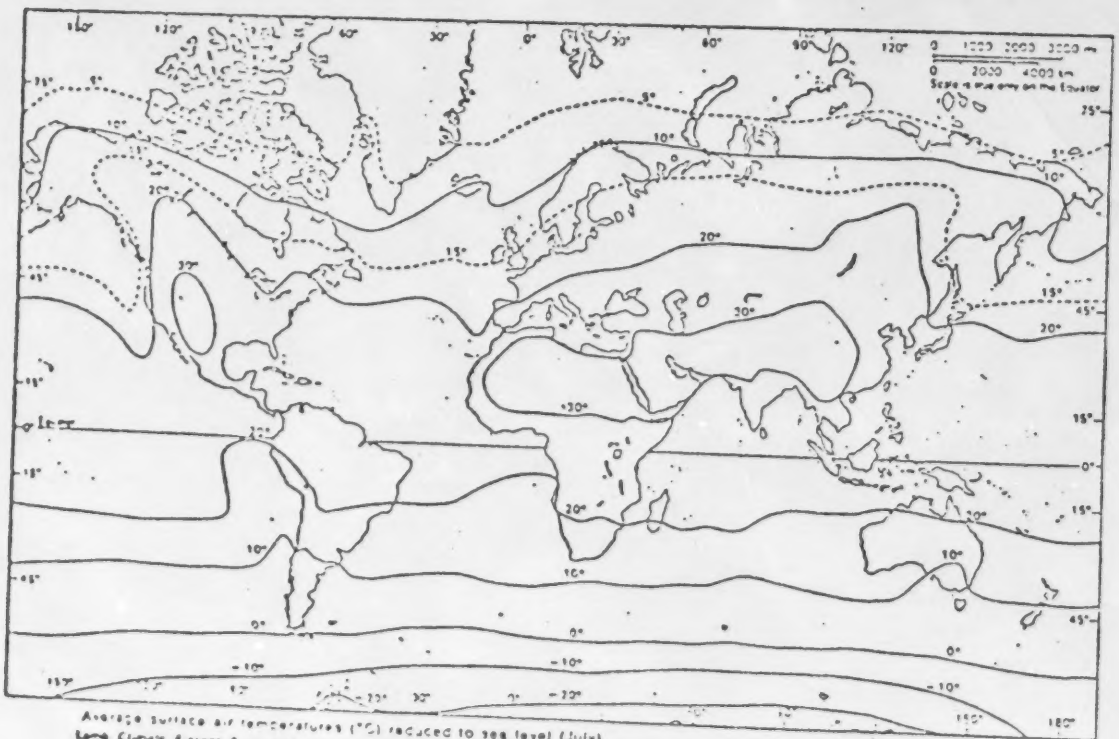


FIGURE 2.3

FIGURE 2.4 - WORLD ISOTHERM MAPS - JANUARY AND JULY



Average surface air temperatures (°C) reduced to sea level (January).



Average surface air temperatures (°C) reduced to sea level (July).
Lamb, Climate, Present, Past and Future, Methuen & Co. Ltd.

CLIMATOLOGICAL AVERAGES AND EXTREMES

	TEMPERATURE(°F)				PRECIPITATION (INCHES)											
	A	B	C	D	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annua
ABILENE	94	33	111	- 9	.88	1.09	1.04	2.27	4.33	2.67	2.28	1.47	2.07	2.35	1.11	1.26	23.32
AMARILLO	92	21	108	-16	.65	.62	.82	1.32	3.37	2.89	2.34	2.58	1.89	1.76	.66	.77	19.67
ANGLETON	91	46	105	10	3.63	3.84	3.18	3.20	3.90	3.51	5.53	4.82	5.44	3.80	3.70	4.61	49.16
AUSTIN	95	41	109	- 2	2.35	2.58	2.13	3.55	3.71	3.22	2.18	1.94	3.44	2.83	2.12	2.53	32.58
BAY CITY	93	43	106	11	3.00	3.03	2.17	2.91	4.32	4.20	3.34	4.83	5.83	3.65	3.09	3.47	43.84
BEAUMONT	93	44	108	4	4.57	4.38	2.82	4.43	4.79	4.75	5.71	5.34	5.30	3.19	4.54	4.95	54.77
BELVILLE	95	45	111	5	2.08	1.76	1.78	2.44	3.24	2.99	2.87	2.20	3.64	2.48	1.90	2.23	29.61
BRENHAM	95	43	111	- 2	3.22	3.11	2.74	3.58	4.18	3.29	2.88	2.88	2.88	2.86	3.81	3.89	39.12
BROWNSVILLE	93	52	104	12	1.36	1.31	1.07	1.37	2.55	2.63	1.73	2.54	5.51	3.22	1.78	1.55	26.65
CLEBURNE	96	35	114	- 3	2.04	2.64	2.35	3.79	4.46	2.92	2.17	2.25	2.78	2.94	2.28	2.58	33.20
CORPUS CHRISTI	94	47	105	11	1.63	1.70	1.44	2.14	2.99	2.39	2.32	2.77	4.40	2.76	1.72	2.08	28.34
CORSICANA	96	36	113	- 7	2.86	3.00	2.88	4.32	4.98	3.12	1.90	2.19	2.67	2.96	2.97	3.21	37.06
DALLAS	95	36	111	- 3	2.32	2.55	2.85	4.00	4.83	3.24	1.94	1.93	2.82	2.70	2.70	2.67	34.55
DENISON DAM	95	31	109	2	1.62	2.62	2.53	4.65	4.77	3.88	2.81	2.49	3.92	2.81	2.55	2.22	36.87
DENTON	96	34	113	- 3	1.90	2.42	2.51	3.69	5.03	3.16	2.05	1.73	2.37	2.46	2.05	2.19	31.56
DUMAS	93	20	109	-18	.60	.54	.78	1.30	2.95	2.45	2.60	2.62	1.55	1.60	.64	.70	18.33
EL PASO	94	32	109	- 8	.46	.41	.35	.29	.40	.69	1.29	1.19	1.14	.85	.33	.49	7.89
FORT WORTH	96	35	112	- 8	2.04	2.24	2.51	3.60	4.59	2.98	1.75	1.68	2.54	2.59	2.46	2.35	31.33
GAINESVILLE	96	32	114	-12	2.07	2.51	2.64	3.75	5.09	3.79	2.38	2.45	2.63	2.91	2.09	2.23	34.54
GALVESTON	87	42	101	8	3.46	2.88	2.86	2.59	2.79	2.65	4.79	4.39	5.09	2.86	3.56	3.89	41.81
GONZALES	96	42	106	18	2.15	2.32	1.96	3.55	3.71	2.91	2.79	2.43	3.54	2.42	2.42	2.53	32.73
GREENVILLE	94	34	116	- 4	2.89	3.31	3.56	4.75	5.72	4.20	3.18	2.27	2.92	3.21	3.54	3.26	42.81
HOUSTON	93	45	109	5	3.78	3.44	2.67	3.24	4.32	3.69	4.29	4.27	4.26	3.77	3.86	4.36	45.95
KERRVILLE	94	34	110	- 7	1.86	2.07	2.02	3.07	4.19	2.99	2.32	1.85	4.22	3.14	1.52	2.25	31.50
KINGSVILLE	96	48	108	11	1.65	1.50	1.30	2.05	3.00	2.30	2.00	2.50	4.75	2.45	1.38	1.62	26.50
LUBBOCK	92	25	107	-16	.68	.57	.73	1.15	3.18	2.53	2.01	1.68	2.36	2.00	.54	.65	18.08
MARSHALL	95	37	112	- 9	4.75	4.01	4.40	4.43	5.25	3.18	3.28	2.53	2.70	3.01	4.41	5.01	46.96
McALLEN	96	48	106	17	1.18	1.03	.66	1.56	2.19	2.36	.88	1.84	3.69	2.58	.98	.84	19.79
McKINNEY	96	34	118	- 7	2.21	2.59	2.78	3.97	5.28	3.22	2.42	1.78	2.82	2.95	2.61	2.17	34.80
MEMPHIS	98	26	117	-11	.76	.77	.89	1.76	4.28	2.78	1.84	1.62	2.07	2.01	.50	.63	19.91
MIDLAND	95	31	109	-11	.80	.60	.36	.83	2.08	1.63	1.88	1.48	1.79	1.66	.47	.66	14.24
MULESHOE	92	20	110	-21	.65	.48	.62	1.02	2.80	2.48	2.37	2.21	1.99	1.62	.55	.65	17.44
PAMPA	94	23	109	-12	.53	.69	.79	1.50	3.62	3.00	2.48	2.39	1.91	1.83	.61	.81	20.16
PARIS	94	34	115	-13	3.08	3.45	3.47	5.19	5.40	4.26	3.65	2.73	3.52	3.22	3.78	3.36	45.11
PLAINVIEW	93	26	108	- 8	.80	.62	.68	1.53	3.18	2.58	2.47	2.05	2.02	1.64	.59	.82	18.96
PORT ARTHUR	91	44	107	11	4.23	4.45	3.44	3.94	4.94	4.29	6.00	5.49	4.88	2.88	3.46	5.09	53.09
SAN ANTONIO	94	42	107	0	1.74	1.65	1.67	2.82	3.45	2.95	2.09	2.36	3.49	2.50	1.37	1.75	27.84
TYLER	94	37	106	- 8	3.98	3.67	3.91	4.89	5.45	3.27	3.26	2.91	2.74	3.23	4.21	4.77	46.19
VICTORIA	92	46	110	9	2.34	2.34	2.32	2.62	4.12	3.04	3.61	3.13	4.23	3.45	2.36	2.61	36.20
WACO	96	38	112	- 5	2.27	2.42	2.35	3.88	4.57	2.67	1.99	1.66	2.77	2.55	2.19	2.74	32.08
WEATHERFORD	96	34	113	-11	2.14	2.46	2.16	3.58	5.39	3.00	1.80	1.67	2.70	3.04	1.82	2.12	31.37
WICHITA FALLS	97	31	113	-12	1.12	1.38	1.54	2.53	4.60	3.20	1.97	1.79	2.33	2.87	1.42	1.45	26.20

A - Average July Temperature
B - Average January Temperature
C - Record Highest
D - Record Lowest

NOTE: Data compiled through 1974 except where noted otherwise:
1 - Period of Record, 1943-1973
2 - Period of Record, 1937-1967
3 - Period of Record, 1934-1970
4 - Period of Record, 1940-1967
5 - Period of Record, 1942-1973

FIGURE 2.6 – CLIMATOLOGY OF SIX TEXAS CITIES

BROWNSVILLE — Elevation 19 Ft.

	Temperature Average Maximum	Temperature Average Minimum	Temperature Average Monthly	Temperature Extreme Highest	Temperature Extreme Lowest	Degree Days (Base 65°) Heating	Degree Days (Base 65°) Cooling	Rel. Hum 12:00 p.m.	Prec. Nor. Total	Prec. Nor. Snow Total	Wind Speed	Wind Direction	Average Number of Days of Sunup/Sundown % Poss. Sunshine	Clr.	P. C.	Cldy.	Rain .01"	Snow 1.0"	Thunder	Fog	Percent IFR
J	71	53	63	83	33	201	185	66	1	T	12		66	45	7	7	17	7	0	1	5	14
F	73	55	64	83	32	174	162	63	1	T	13		68	49	7	8	13	6	0	1	3	16
M	77	59	68	93	35	76	268	58	1	T	12		68	51	8	9	16	4	0	1	3	14
A	83	65	74	96	48	0	396	59	2	T	14		68	68	9	11	14	4	0	2	2	9
M	87	71	79	99	57	0	636	58	3	0	13		68	68	8	15	10	5	0	3	1	8
J	91	74	83	101	63	0	849	58	3	0	13		72	72	8	16	6	5	0	2	*	4
J	93	76	84	103	70	0	918	56	2	0	12		81	81	11	15	5	4	0	2	*	1
A	93	75	84	103	69	0	906	57	2	0	12		81	81	11	14	6	7	0	4	*	1
S	92	73	83	99	56	0	699	64	3	0	10		86	86	9	13	8	10	0	4	*	2
O	85	67	76	92	48	0	375	62	4	0	10		66	66	7	8	16	6	0	1	*	4
N	77	56	66	94	35	66	153	65	3	0	11		52	52	9	8	12	8	0	1	3	6
D	73	54	63	87	34	144	143	63	2	T	11		46	46	7	8	16	6	0	*	4	14
Y	83	65	74	109	33	800	4200	63	33	T	12		81	81	97	136	133	31	0	33	28	8

DEL RIO — Elevation 1026 Ft.

	Temperature Average Maximum	Temperature Average Minimum	Temperature Average Monthly	Temperature Extreme Highest	Temperature Extreme Lowest	Degree Days (Base 65°) Heating	Degree Days (Base 65°) Cooling	Rel. Hum 12:00 p.m.	Prec. Nor. Total	Prec. Nor. Snow Total	Wind Speed	Wind Direction	Average Number of Days of Sunup/Sundown % Poss. Sunshine	Clr.	P. C.	Cldy.	Rain .01"	Snow 1.0"	Thunder	Fog
J	64	39	51	89	18	439	10	M	1	T	8		na	11	6	14	4	0	*	4
F	69	43	56	88	21	258	19	52	1	T	10		na	10	5	13	5	*	1	2
M	77	49	63	101	25	147	114	49	1	T	11		na	11	8	12	4	*	1	1
A	85	58	72	102	38	18	196	53	1	0	10		na	7	7	16	3	0	1	*
M	91	68	78	103	45	0	421	57	3	0	11		na	8	9	14	5	0	3	*
J	97	72	84	105	55	0	461	58	2	0	12		na	8	14	10	6	0	5	0
J	99	74	86	108	66	0	534	50	1	0	11		na	13	12	6	3	0	3	0
A	98	74	86	109	64	0	429	53	1	0	10		na	10	12	9	6	0	4	0
S	92	68	80	103	48	0	423	57	3	0	9		na	9	11	10	8	0	3	*
O	83	59	71	94	36	31	201	57	2	T	9		na	12	8	11	4	0	2	1
N	71	45	58	91	25	218	43	67	1	0	8		na	11	7	12	4	0	1	3
D	65	40	52	84	23	324	9	56	1	T	8		na	11	5	15	5	0	1	5
Y	83	57	70	109	18	1504	2859	54	18	1	10		na	117	104	144	58	*	25	16

CORPUS CHRISTI — Elevation 41 Ft.

	Temperature Average Maximum	Temperature Average Minimum	Temperature Average Monthly	Temperature Extreme Highest	Temperature Extreme Lowest	Degree Days (Base 65°) Heating	Degree Days (Base 65°) Cooling	Rel. Hum 12:00 p.m.	Prec. Nor. Total	Prec. Nor. Snow Total	Wind Speed	Wind Direction	Average Number of Days of Sunup/Sundown % Poss. Sunshine	Clr.	P. C.	Cldy.	Rain .01"	Snow 1.0"	Thunder	Fog
J	61	41	51	91	25	291	88	70	2	T	12		47	9	7	17	6	*	1	5
F	70	51	61	86	26	174	98	71	3	T	13		51	7	6	15	6	0	1	5
M	76	59	68	93	29	109	183	61	1	T	14		55	7	8	16	5	0	2	4
A	83	67	75	97	39	0	327	65	2	0	14		57	5	10	15	5	0	3	3
M	89	73	81	101	49	0	603	64	3	0	13		61	8	12	11	5	0	5	1
J	93	76	85	103	67	0	842	64	2	0	12		73	9	14	7	5	0	3	*
J	94	75	84	105	66	0	885	63	2	0	12		83	11	15	5	4	0	3	*
A	94	75	84	105	64	0	894	61	3	0	11		78	12	12	7	5	0	4	*
S	90	71	81	100	56	0	699	65	4	0	10		68	10	12	8	6	0	4	*
O	85	65	75	93	43	0	357	61	3	0	10		59	13	10	8	7	0	5	*
N	76	54	65	87	29	120	121	65	2	T	11		46	8	7	15	3	0	3	1
D	69	53	61	81	28	220	114	67	2	0	11		46	8	7	16	1	0	1	3
Y	81	62	72	101	25	914	2809	64	28	T	12		64	104	122	139	78	*	31	28

SAN ANTONIO — Elevation 788 Ft.

	Temperature Average Maximum	Temperature Average Minimum	Temperature Average Monthly	Temperature Extreme Highest	Temperature Extreme Lowest	Degree Days (Base 65°) Heating	Degree Days (Base 65°) Cooling	Rel. Hum 12:00 p.m.	Prec. Nor. Total	Prec. Nor. Snow Total	Wind Speed	Wind Direction	Average Number of Days of Sunup/Sundown % Poss. Sunshine	Clr.	P. C.	Cldy.	Rain .01"	Snow 1.0"	Thunder	Fog
J	62	42	52	89	0	428	14	60	2	T	9		49	9	6	15	8	*	1	5
F	66	45	55	92	6	296	36	57	2	T	10		52	8	6	14	7	0	1	5
M	72	50	61	100	21	195	120	53	2	T	11		55	8	8	15	7	0	2	3
A	79	58	69	99	34	59	189	56	3	0	11		55	7	8	15	7	0	3	3
M	85	65	75	101	44	0	414	57	3	0	10		58	7	11	13	8	0	5	1
J	92	72	82	103	53	0	554	54	3	0	10		69	7	16	7	6	0	4	1
J	94	74	84	105	62	0	655	49	2	0	9		77	10	15	6	4	0	3	*
A	94	73	84	106	61	0	509	49	2	0	8		75	11	14	6	5	0	4	*
S	89	69	79	102	41	0	453	56	3	0	8		70	10	12	8	7	0	4	*
O	82	60	71	95	33	31	281	53	3	0	8		67	12	10	9	6	0	2	2
N	70	49	60	91	23	204	81	54	1	0	9		57	11	7	12	6	0	2	2
D	65	42	54	90	14	363	31	58	2	T	9		52	10	8	13	7	0	1	5
Y	79	58	69	106	0	1546	3068	54	28	T	9		61	110	119	136	78	*	35	23

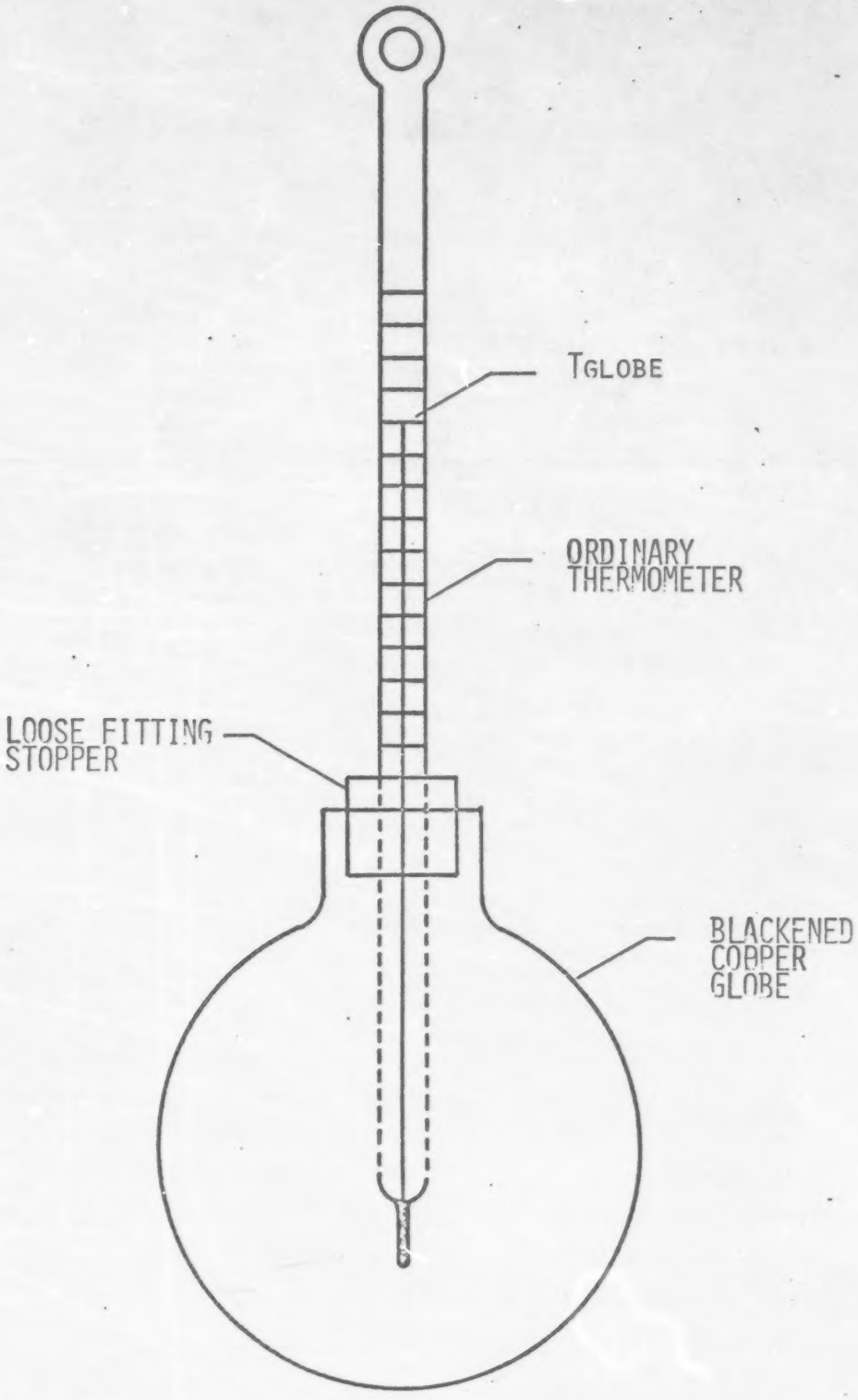
DALLAS — Elevation 481 Ft.

	Temperature Average Maximum	Temperature Average Minimum	Temperature Average Monthly	Temperature Extreme Highest	Temperature Extreme Lowest	Degree Days (Base 65°) Heating	Degree Days (Base 65°) Cooling	Rel. Hum 12:00 p.m.	Prec. Nor. Total	Prec. Nor. Snow Total	Wind Speed	Wind Direction	Average Number of Days of Sunup/Sundown % Poss. Sunshine	Clr.	P. C.	Cldy.	Rain .01"	Snow 1.0"	Thunder	Fog	Percent IFR
J	56	36	46	84	8	651	0	59	2	T	11		51	10	5	16	7	1	1	2	17
F	60	39	50	89	16	465	0	56	3	T	11		53	9	6	13	8	*	1	1	11
M	68	45	56	92	18	313	28	54	3	0	12		56	10	7	14	8	*	2	1	7
A	76	54	65	97	33	80	113	54	3	0	12		57	8	7	14	8	0	3	*	3
M	83	63	73	98	42	8	315	57	3	0	12		61	8	10	13	8	0	6	*	10
J	91	72	81	102	58	0	618	59	3	0	12		71	9	13	8	7	0	7	*	3
J	95	75	85	105	63	0	842	60	2	0	10		83	11	17	3	8	0	5	*	1
A	95	75	85	105	61	0	911	61	3	0	10		77	11	14	6	5	0	4	*	2
S	88	69	78	101	49	0	636	66	3	0	9		74	10	10	10	5	0	4	*	1
O	79	55	67	93	29	62	192	69	3	0	9		66	14	8	9	5	0	2	*	4
N	66	44	55	84	21	321	26	71	3	0	10		55	11	5	14	6	0	2	1	9
D	58	37	48	83	10	524	3	69	3	0	10		55	13	6	11	6	0	2	1	10
Y	76	54	65	107	8	3263	2833	66	33	1	11		63	131	93	132	78	1	40	8	7

VICTORIA — Elevation 104 Ft.

	Temperature Average Maximum	Temperature Average Minimum	Temperature Average Monthly	Temperature Extreme Highest	Temperature Extreme Lowest	Degree Days (Base 65°) Heating	Degree Days (Base 65°) Cooling	Rel. Hum 12:00 p.m.	Prec. Nor. Total	Prec. Nor. Snow Total	Wind Speed	Wind Direction	Average Number of Days of Sunup/Sundown % Poss. Sunshine	Clr.	P. C.	Cldy.	Rain .01"	Snow 1.0"	Thunder	Fog
J	65	46	55	88	16	344	70	64	2	T	11		na	7	7	17	8	*	1	4
F	69	49	59	90	22	230	95	59	2	T	11		na	8	5	15	7	0	2	2
M	73	54	63	95	28	152	104	57	2	0	12		na	6	9	16	7	0	2	1
A	79	61	70	99	36	31	179	60	3	0	12		na	4	8	18	5	0	3	*
M	85	68	76	101	49	0	360	60	4	0	11		na	4	11	16	7	0	5	*
J	90	73	81	99	59	0	540	59	3	0	10		na	4	12	9	7	0	6	*
J	92	75	83	104	62	0	633	55	4	0	9		na	6	15	9	8	0	5	*
A	92	74	83	102	63	0	598	54	3	0	9		na	7	15	9	8	0	5	*
S	88	71	79	93	51	0	452	61	4	0	9		na	7	12	10	11	0	5	*
O	80	62	71	95	28	6	303	65	3	0	9		na	12	10	9	5	0	3	1
N	73	52	62	92	27	150	78	66	2	0	10		na	10	9	11	5	0	1	3
D	67	48	57	88	23	270	58	63	3	T	10		na	7	5	19	8	0	1	3
Y	79	61	70	107	16	1173	3370	59	35	T	10		na	82	125	158	82	0	44	42

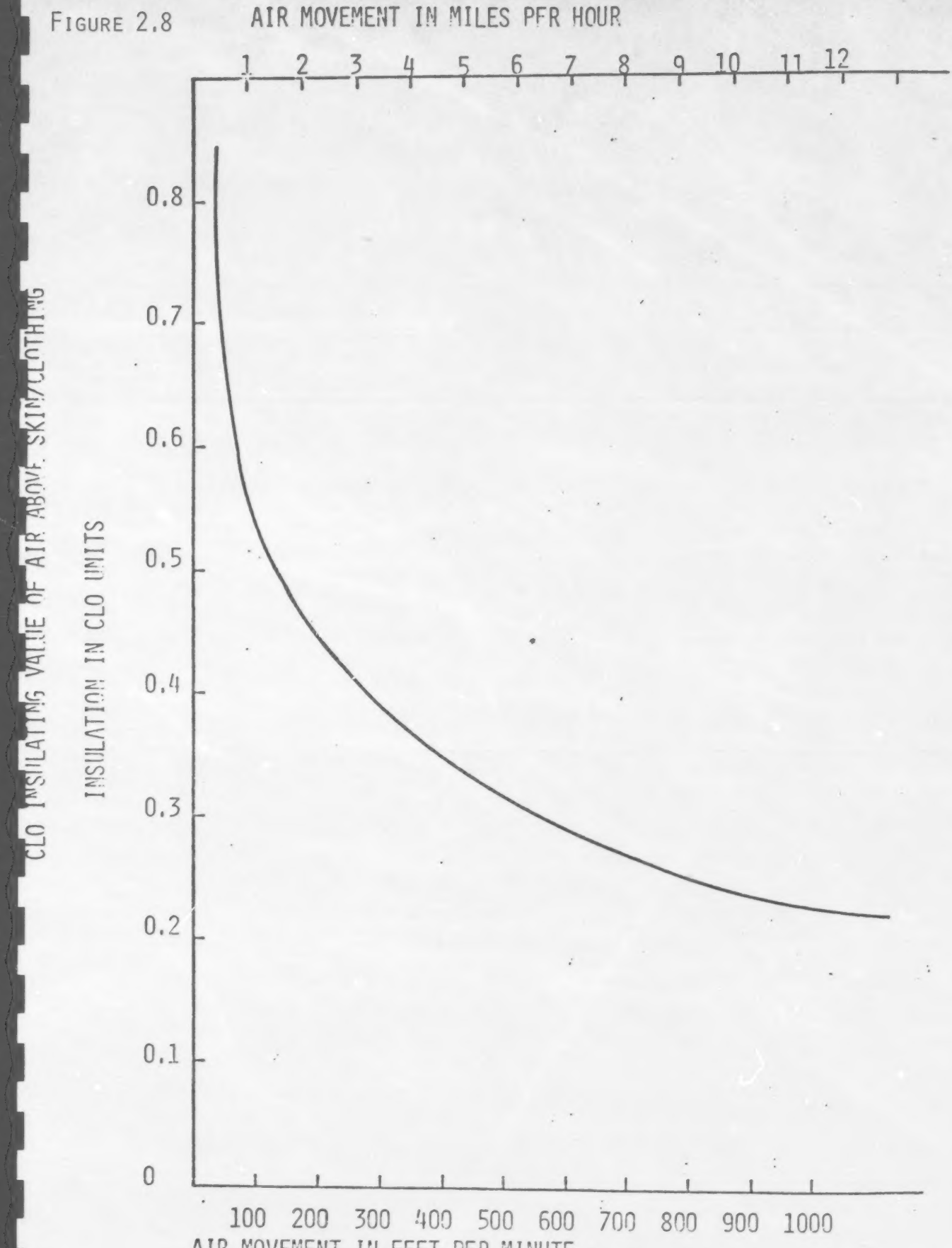
Source : Weather Tables



GLOBE THERMOMETER FOR DETERMINING MEAN RADIANT TEMPERATURE

FIGURE 2.7

FIGURE 2.8



INSULATING POWER OF THE AMBIENT AIR AS A FUNCTION OF WIND VELOCITY AT 77 F.

FIGURE 2.9

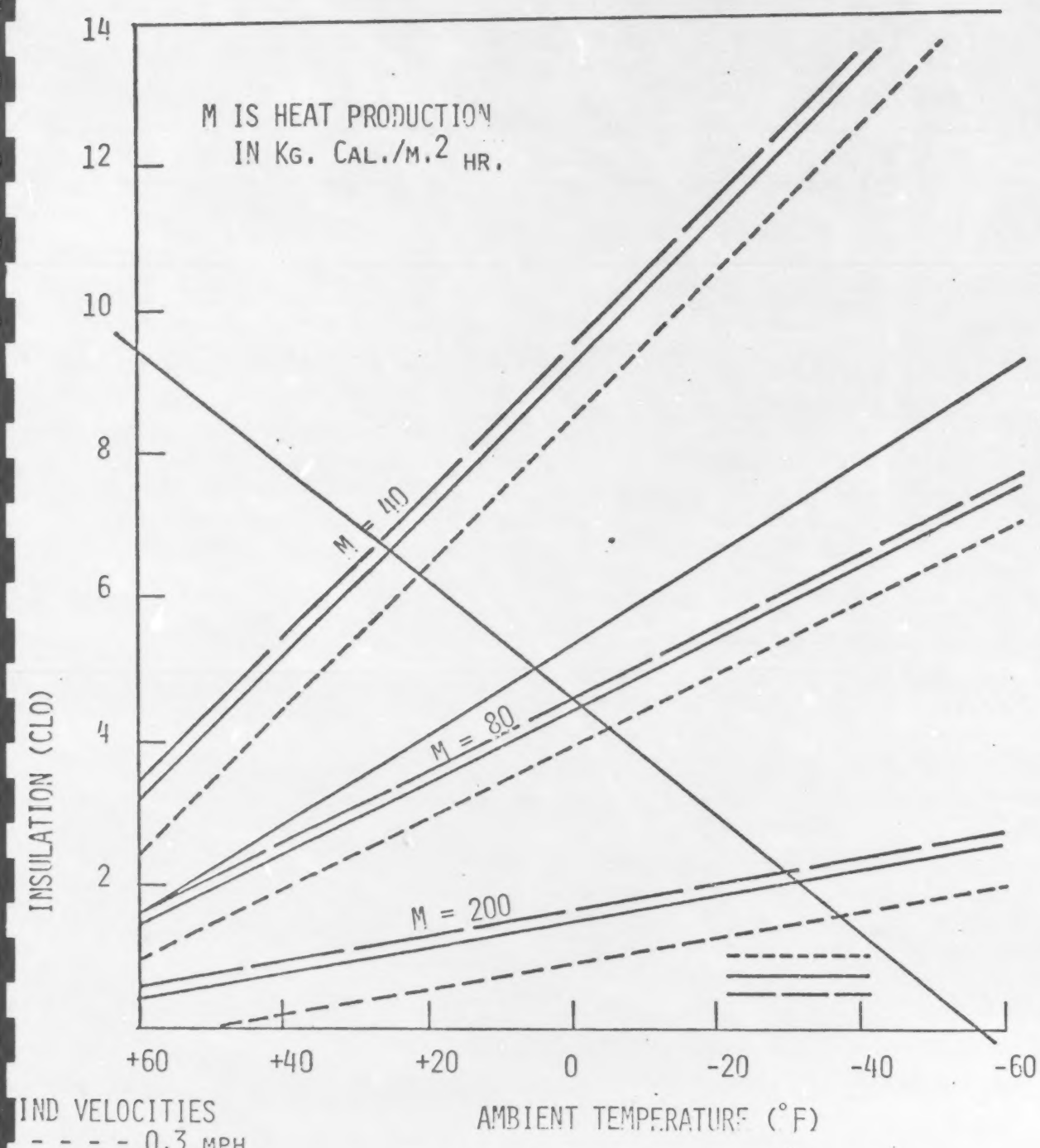

M IS HEAT PRODUCTION
IN KG. CAL./M.2 HR.
14
12
10
8
6
4
2
M = 40
M = 80
M = 200
INSULATION (CLO)
+60
+40
+20
0
-20
-40
-60
AMBIENT TEMPERATURE (°F)
IND VELOCITIES
0.3 MPH
5.0 MPH
25.0 MPH

FIGURE 2.10

OUTDOOR TDB/TWB CHART FOR REPRESENTATIVE TEXAS CITIES

	Higher Summer TDB			Lowest Winter TDB		Daily TDB Range	Highest TWB
	1	2	3	4	5	6	7
WICHITA FALLS	103/73°	101/73°	98/73°	14	18	24	75-77
DALLAS	102/75°	100/75°	97/75°	18	22	20	77-78
CORSICANA	100/75°	98/75°	96/75°	20	25	21	77-79
AUSTIN	100/74°	98/74°	97/74°	24	28	22	77-78
EL PASO	100/64°	98/64°	96/64°	20	24	27	68-69
SAN ANTONIO	99/72°	97/73°	96/73°	25	30	19	76-77
AMARILLO	98/67°	95/67°	93/67°	6	11	26	70-71
HOUSTON	97/77°	95/77°	93/77°	28	33	18	79-80
CORPUS CHRISTI	95/78°	94/78°	92/78°	31	35	19	79-80

ALL VALUES IN °F TDB/TWB EXCEPT WHERE INDICATED

1. COLUMN 1, 2 AND 3 GIVE TDB/TWB FOR 1%, 2-1/2% AND 5% OF SUMMER DAYS. ONLY 1 DAY IN 100 IS COLUMN 1 EXCEEDED; ONLY ON 2-1/2 DAYS IS COLUMN 2 EXCEEDED AND SO ON.

2. COLUMNS 4 AND 5 GIVE TDB FOR 99% AND 97-1/2% OF WINTER DAYS. IN 99% (97-1/2%) OF WINTER DAYS, THESE VALUES ARE EXCEEDED.

3. COLUMN 6 SHOWS THE MEAN DAILY RANGE IN TDB. THUS, EL PASO COMMONLY EXPERIENCES A TDB FLUCTUATION OF 27°F BETWEEN THE HOTTEST HOUR DURING THE DAY AND THE COLDEST HOUR DURING THE NIGHT.

4. COLUMN 7 SHOWS TWB FOR THE 15 DAYS WHEN THE ATMOSPHERE WAS MOST HUMID IN A RECENT 5 YEAR PERIOD. THUS, CORPUS CHRISTI AND HOUSTON EXPERIENCE GREATER HUMIDITY THAN AMARILLO AND EL PASO.

FIGURE 3.1

OCCUPANCY AND DURATION OF STAY IN BUILDING TYPES

SPACE OR BUILDING	OCCUPANCY	DURATION OF STAY PER PERSON
1. ENTRANCE LOBBIES	FEW AT A TIME	SHORT
2. ELEVATORS	ONE OR SEVERAL	SHORT
3. CONVENIENCE STORES	SEVERAL	MINUTES
4. RESTAURANTS	VARIABLE	1/2 - 1 HOUR
5. CLASSROOM	SUBSTANTIAL	3/4 - 1 1/2 HOURS
6. LIBRARIES	SEVERAL OR MANY	VARIABLE
7. CHURCHES	SUBSTANTIAL	1-2 HOURS
8. SPORTS ARENAS	THOUSANDS	2-3 HOURS
9. MOVIE THEATERS	HUNDERDS	2-4 HOURS
10. OFFICES	FEW	8 HOURS
11. MOTEL ROOM	ONE OR TWO	8 HOURS OR MORE
12. HOSPITAL ROOM	ONE OR TWO	24 HOURS OR MORE

"COMFORTABLE" LINES FOR MEN EXPOSURE PERIODS OF 1.0, 2.0, AND 3.0 HRS

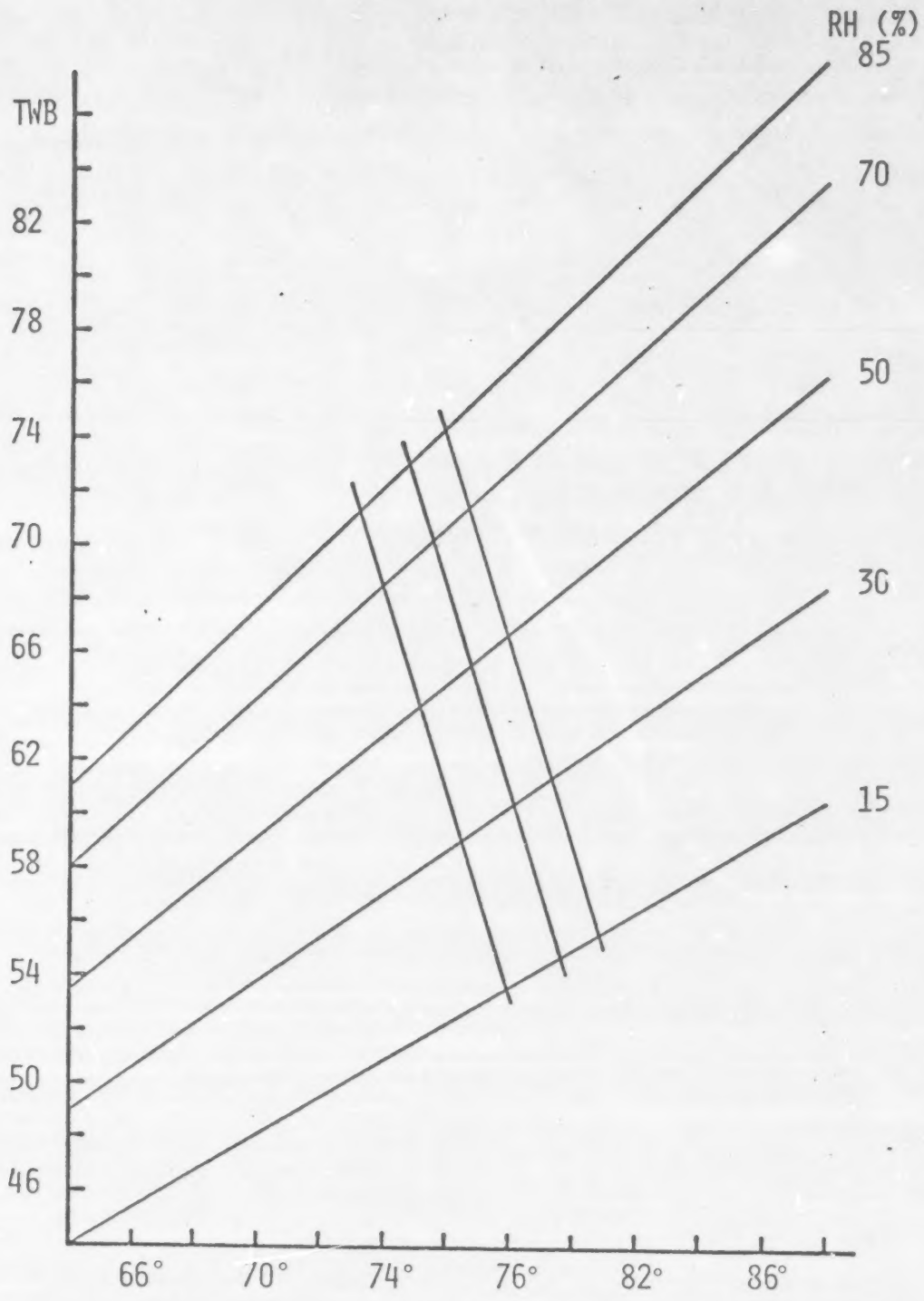


FIGURE 3.2

"COMFORTABLE" LINES FOR WOMEN FOR EXPOSURE PERIODS OF 1.0, 2.0 AND 3.0 HRS

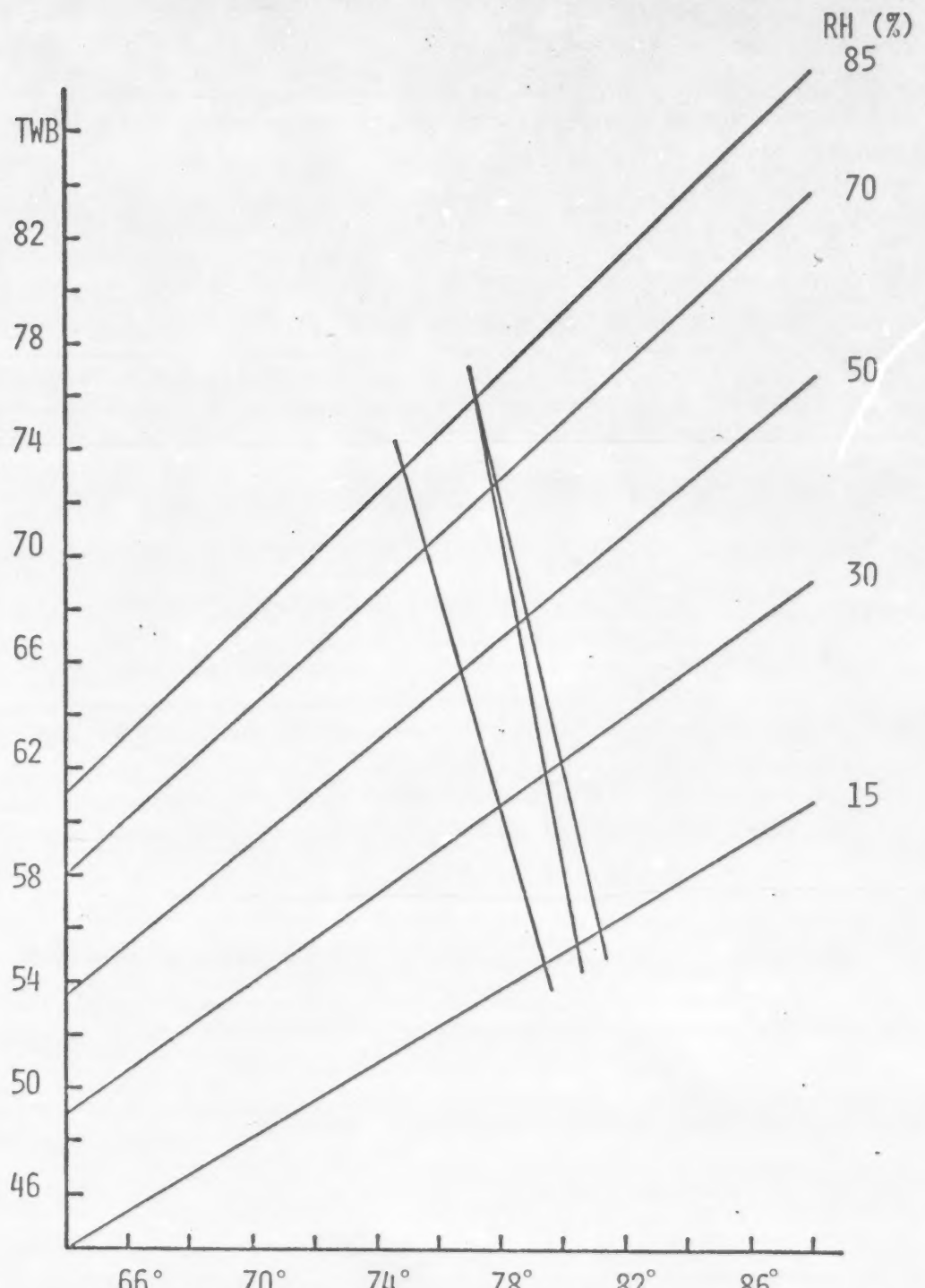


FIGURE 3.2

aa

"COMFORTABLE" LINES FOR MEN AND WOMEN FOR AN EXPOSURE PERIOD OF 1.0 HR

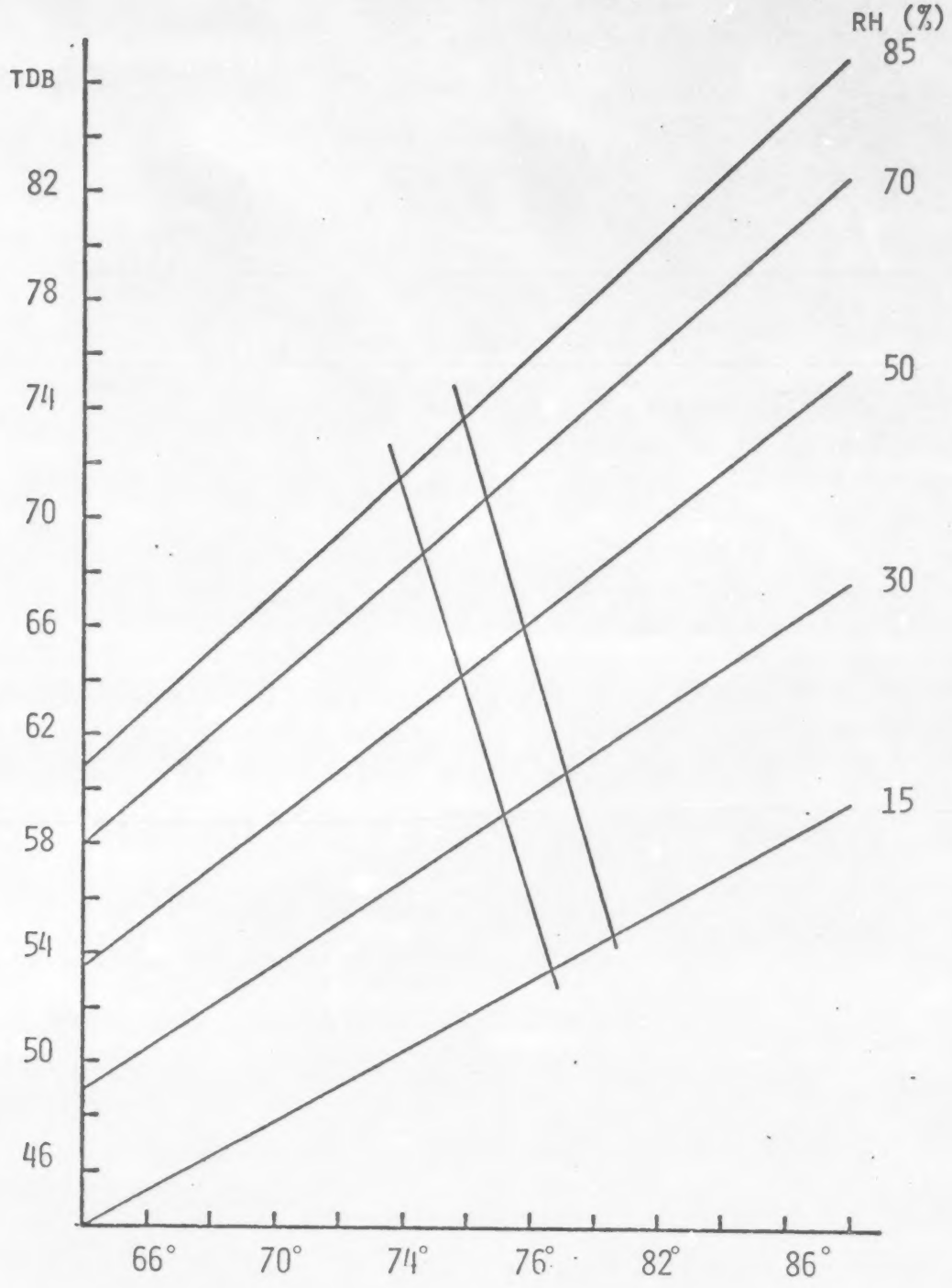


FIGURE 3.2

FIGURE 3.3
TABLE OF HEAT PRODUCTION RATES

	Typical values for BTU/hr
Asleep	
Sleeping, men over 40	260
Sleeping, men aged 30-40	280
Sleeping, men aged 20-30	280
Resting	
Lying moderately relaxed	320
Lying awake--after meals	340
Sitting at rest	400
Very light activity--seated	
Writing	430
Typing	550
Polishing	570
Very light activity--standing	
Relaxed	440
Typing	460
Polishing	480
Light activity--seated	
Playing musical instruments	690
Repairing boots and shoes	720
At lecture	730
Light activity--standing	
Washing clothes	610
Ironing	890
Scrubbing	1040
Light activity--moving	
Slow movement about room	600
Vehicle repair	820
Washing	1000
Moderate activity--sitting	
Rowing for pleasure	1190
Cycling at 8-11 mph	1360
Cycling rapidly	1640

FIGURE 3.3 CONTINUED:

	Typical values for BTU/hr
Moderate activity--standing	
Gardening	1380
Chopping wood slowly	1480
Shoveling sand slowly	1620
Moderate activity--moving	
Golf	1290
Table tennis	1380
Tennis	1500
Heavy activity--lying	
Leg exercises, average	1790
Swimming breast stroke at 1.6 mph	1950
Swimming backstroke at 1.0 mph	1980
Heavy activity--sitting	
Cycling rapidly--own pace	1980
Cycling at 10 mph--heavy bicycle	2120
Cycling in race 100 mi in 4 hr., 22 min.	2340
Heavy activity--standing	
Chopping wood rapidly	1790
Shoveling sand rapidly	1830
Sawing wood by hand	1900
Heavy activity--moving	
Skating at 9 mph	1860
Skiing at 8 mph on level	2140
Climbing stairs at 116 steps per minute	2340
Very heavy activity--sitting	
Cycling at 13.2 mph	2380
Galloping on horseback	2720
Sculling 97 strokes/min.	3000

FIGURE 3.3 CONTINUED:

	Typical values for BTU/hr
Very heavy activity--moving	
Fencing	2500
Playing basketball	2720
Climbing stairs	2860
Extreme activity	
Wresling	3100
Marching at double	3160
Enduration marching	3520

Note:

BTU/hr is the rate of heat production per hour. These measurements are given for a person 69 inches tall and 167 pounds in absolute units.

FIGURE 3.4
HEAT LOSS

Typical Activity	Evaporative Heat Loss	Clo for Heat Balance
SLEEPING	53 BTU/HR.	0.6 LIGHT WINTER CLOTHING
SCRUBBING	226 BTU/HR.	0.14 T-SHIRT & BRIEFS, BRA & SHORTS
CLIMBING STAIRS	644 BTU/HR.	0.05 BRIEFS ONLY

ff